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DESCRIPTION OF THE GULF OF CUTCH

AND OF THE

LESSER RAN OF CUTCH,

WITH

APPENDIX GIVING AN ACCOUNT OF THE TIDAL OBSERVATIONS IN THE GULF OF CUTCH,

BEING A PORTION OF THE

KÁTHIÁWÁR GAZETTEER.

WRITTEN BY

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of the Hansthal creek. The observations were carried out with the greatest success, and the following are some of the results obtained:

At Okha (mouth of the gulf) the greatest range of the tide was found to be	14·8 feet.
At Nowanár (half-way up the gulf) the greatest range registered was	19·6 ,,
At Hansthal (at the head of the gulf) the greatest range was found to be	20·2 ,,

or 2 to 4 feet more than the range given in the marine charts up to that date.

By the combination of some of the values derived from the tidal observations and the results of the levelling operations, the mean level of the sea at the head of the gulf was found to be 7 inches higher than it was at the open sea coast, and at Nowanár, half-way up the gulf, the mean sea-level was 4 inches higher than it is at the mouth of the gulf.

The approximate values of the progress of the tidal wave up and down the gulf may be taken as under:

	h.	m.	
High water, Nowanár, half-way up ...	1	5	after Okha, mouth of gulf.
,, Hansthal, head of gulf ...	1	40	,, ,,
Low water at Nowanár, half way up...	1	36	,, ,,
,, Hansthal, head of gulf...	2	53	,, ,,

The reduction of the tidal and meteorological observations by what is termed Harmonic Analysis was carried out by Captain Baird, R.E., and the values of the amplitudes and epochs were determined, thus affording all data requisite for the prediction of the Tides.* The results were interesting, and some of these it may not be out of place to describe.

		S	M	K	O	P	J	Q	L	N	λ	ν	μ	MS	2SM
		Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft	Ft.	Ft.	Ft.	Ft.	Ft.
OKHA.	R 1	·0741	·1122	1·5605	·8095	·3844	·1231	·1596							
	E 1	149·89	120·86	146·60	322·67	319·94	176·32	324·68							
	R 2	1·2224	3·6936	·4207	...	...	...	...	·1511	·7551	·0712	·1592	·1896	...	·0435
	E 2	14·37	348·08	24·82	...	...	...	...	224·77	322·94	204·40	8·50	184·26	...	291·24
	R 3	...	·0289												
	E 3	...	22·10												
	R 4	·0132	·1265	...	...	...	...	...	...	...	...	...	...	·0619	
	E 4	116·57	108·88	...	...	...	...	...	...	...	...	...	...	112·37	
	R 6	·0030	·0056												
	E 6	20·92	272·57												
	R 8	·0006	·0102												
	E 8	219·81	100·06												
NOWANAR.	R 1	...	...	1·6857	·7987	·2806	·1698	·1697							
	E 1	...	...	156·00	332·04	342·02	191·77	335·14							
	R 2	1·8933	5·848	·4780	...	...	...	...	·3569	1·2205	·1466	·2965	·4026	Not available, probably about the same as for **Okha.**	
	E 2														
	R 4	·0131	·1023												
	E 4	350·56	275·00												
HANSTHAL.	R 1	·1292	·1208	1·6502	·8807	·3839	·1091	·1618							
	E 1	164·01	155·61	174·60	340·76	353·65	222·61	343·23							
	R 2	1·9277	6·6291	·6767	...	...	...	...	·3892	1·1535	·2268	·2864	·5569	...	·1309
	E 2	84·51	46·52	88·63	...	...	...	...	238·32	26·76	219·57	48·24	179·74	...	297·74
	R 3	...	·0534												
	E 3	...	93·55												
	R 4	·0211	·6803	...	...	...	...	...	...	...	...	...	...	·3388	
	E 4	61·74	331·55	...	...	...	...	...	...	...	...	...	...	13·01	
	R 6	·0069	·2760												
	E 6	166·57	248·94												
	R 8	·0025	·0726												
	E 8	150·63	154·36												

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The diurnal components of the tides of the gulf are found to have exaggerated effects corroborating what has hitherto been found in all Indian Ocean tide deductions. These are the components which form the peculiar feature of diurnal inequality, *i.e.*, a high water, say at 10 A.M., will be followed by a high water about 10-30 P.M., much higher or lower as the case may be: this holds good also in the low waters. Perhaps one of the most remarkable features of the tides of the gulf is the practically uniform values of the diurnal tides at the three stations, Okha, Nowanár, and Hansthal, and it would appear that the diurnal portions of the tidal wave do not suffer any augmentation similar to the semi-diurnal portions in passing over shallow and contracted channels. This is a feature which, it is believed, has not previously been recognized. The proportion obtained between the two chief tides (the solar and lunar semi-diurnal), is about 1 to 3 from Okha and Nowanár and as 1 to 3½ at Hansthal; this proportion, although larger than what is given by theory (1 to 2·1), is about the same as that obtained at other places in India; the increased proportion at Hansthal is also in accordance with that observed at other places, the ratio appearing to increase as the stream passes over shallow places.

The effect of friction is clearly shown in the formation of what are called *over-tides*, and also from their rapid augmentation as the tidal wave goes up the gulf, the tidal wave being deep in comparison to the depth of the channel.

The first attempts made to discover the effects of wind and of atmospheric pressure on the tide were made from the Gulf of Cutch observations, but they were not altogether satisfactory on account of the changes of the velocity and direction of the wind, occurring, as a rule, simultaneously with change of atmospheric pressure. High water on full and change may be taken as about 0 hour 0 minute at the Bet side of the mouth of the gulf, and as about 0 hour 15 minutes at Cutch Mándvi; at Nowanár and Mundra about 1 hour 20 minutes; at Bedi bandar on the opposite coast near Navánagar at about 1 hour 40 minutes, and at Jodiya bandar from 1 hour 45 minutes to 2 hours 0 minute.

Wind and Weather.

The following account of the wind and weather of the Gulf of Cutch from the "Sailing Directory" agrees in the main with the results obtained by the self-registering anemometers and aneroids in Captain Baird's observatories:

> "In the Gulf of Cutch West and S.W. winds prevail from February to October, inclusive, and N.-Easters in November, December and January. In the latter month it occasionally blows fresh, but never more than two or three days at a time, followed by light winds and calms or light sea-breezes in the afternoon. The barometer *rises* with these strong N.-Easters, and *falls* before W. sea-breezes.
>
> "In the latter end of the month of January and beginning of February, dense banks of fog are frequently seen at early dawn on the horizon, after a calm night; when the sun rises, these drift to sea with the land-winds and are blown back by West winds, obscuring all objects. They generally come in heavy detached masses, wetting everything, and almost obscuring the sun, which, however, shines out with apparently greater warmth during the intervals. These fogs may be expected until the latter end of

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February, and are invariably wet. The same prevails on the coast of Sind at that season, over the swamps of the River Indus.

"From the first week of February fresh breezes, from West to S.W. may be expected; these are indicated by a slight *fall* in the barometer, and last for two days, succeeded by calms or light winds. And, although N.-Easters may still blow occasionally after this date, it is but seldom, and only as a land-wind, in the morning or after midnight, and a slight *rise* of barometer precedes them.

S. W. Monsoon.

"After the beginning of March the West winds may be said to have fully set in; and now calms and light N.E. winds are of only occasional occurrence. Towards the vernal equinox, or some time in the second or third week of March, there are one or two days in which thunder and hail-storms happen at the head of the gulf, in heavy squalls from S.E. to N.E. The barometer gives no warning of these.

"In April, West and S.W. winds prevail, being strongest in the afternoon as a sea-breeze, and moderate from midnight till the next forenoon. From the beginning of May the heavy S.W. monsoon swell has commenced at the entrance of the gulf, and it becomes a difficult matter to work round the N.W. point of Okhámandal, from Bet to Dwárka, even with the strong ebb tides that prevail in that locality, as the swell on the Gurúr shoal is so heavy and confused. Only the larger sort of Cutch Kotiyás attempt it after mid-May, and they have to lie inside Bet and take advantage of any break in the strength of the wind to try and get out.

"From June till the end of August the S.W. monsoon blows with more or less strength, sometimes amounting to a fresh gale. Heavy rain seldom occurs before mid-July and sometimes later, though after the end of June frequent showers happen. After mid-August the most enterprising of the Cutch boatmen leave Mándvi, and lie at Bet, looking out for a break in the weather, which they take advantage of and make the passage to Bombay in three or four days. The first arrivals at Mándvi from Bombay, after the S.W. monsoon, are in the first week of September. After the middle of that month the wind gets considerably weaker, and hauls to about W.N.W. towards midnight. But not until October, when they haul more to the North and become decided land-winds, can a vessel fetch out of the gulf from Mándvi on one tack without going to Bet.

N. E. Monsoon.

"In the beginning of November, the land-winds or N.-Easters may be looked for with certainty, and frequently are of moderate strength. After the middle of the month they blow fresh occasionally, sometimes lasting all day; but, when the forenoon is calm, the sea-breeze may be looked for soon after midday. The sea-breezes off the Cutch coast are a great relief after a dry land-wind. On the Hálár coast the N.-Easters are pleasant.

Gales.

"On November 21st, 1851, a heavy gale from N.E. and South was experienced throughout the gulf, and many boats were wrecked and foundered. It first commenced as a N.E. fresh breeze at day-break (during the previous night there were light squalls from all quarters); the barometer was then much the same as the day before, but afterwards fell (instead of rising as usual) towards 10 o'clock in the forenoon, by which time the wind had gradually veered to S.E. and become a moderate increasing gale. Rain likewise fell. From 11h. A.M. to 3h. P.M., the wind was strongest, blowing a strong S.E. gale at times, in squalls with rain. Towards evening the wind had veered to S.W. and decreased to a strong breeze, but occasionally blowing a moderate gale in squalls. During the night it gradually veered to N.W., at the same

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time decreasing, and the sky clearing, and at daylight the wind was North, but only a fresh breeze. The barometer was lowest at 2h. P.M., and after that hour rose rapidly. In the forenoon of the 22nd it was as high as it had been six days before.

"In December the N.E. winds occasionally blow fresh, but for never more than three or four days at a time. In the afternoon they are very weak, and sometimes there is a calm, or a very light sea-breeze. The E. I. C. sloop *Elphinstone* had a gale in this month, from S.E. and N.E., when about 120 miles to the West of the entrance of the Gulf of Cutch.

Passages.

"During the S.W. monsoon, frequent breaks in the weather occur, thus enabling boats to run between Mándvi and Bet, and between Tuna and Jodiya, but these only last a day or two at a time. Large Cutch Kotiyás, being late in returning from Zanzibár to Mándvi, stop off the latter place and communicate with their owners; then they run over to Chákha sheltered anchorage, to which place small Kotiyás are sent to lighten them of their cargo, and bring it across to Mándvi creek. The large vessel follows at high spring tides and bumps in over the bar of Mándvi creek.

"From November to January the N.-Easters blow fresh outside the gulf, and it is prudent for vessels wishing to work into it to anchor for a few hours off Dwárka, or Kachhigadh, should it be ebb tide, and afterwards start with the flood across the mouth of the gulf to make the Cutch coast, where the water is much smoother. A course of about N. by W., or with spring tides, perhaps a nearly North course from Kachhigadh point, may thus be made good, leading a vessel nicely between the Gurúr and Lushington shoals towards the Cutch coast, along which she may continue working to the East, or if the wind be light, she may anchor to wait for the next flood tide, or till she can make head against the ebb."

Meteorological Observations in 1874.

The greatest velocities registered in 1874-75 by Captain Baird's anemometer in 24 hours, were—

620 miles at Okha on the 20th June,
890 „ at Nowanár on the 26th June,
1130 „ at Hansthal on the 5th August,

and on the latter date the anemometer at Hansthal recorded 270 miles in three hours, between 9 A.M. and noon. Captain Baird was not entirely satisfied with the performances of these instruments, but considering their small size (for the sake of lightness and portability), and their exposure to fierce winds, to rain, and worse than all, to the constant oxidising influence of the sea, it was improbable that any instruments would, under similar circumstances, have given much better results.

Rain-gauges were set up at each tidal station; the total rainfall during the monsoon was—

10·75 inches at Okha.
13·61 „ „ Nowanár.
18·40 „ „ Hansthal.
21·91 „ „ Rájkot (40 miles inland).

It will be seen that, so far, a greater range of tide, a greater velocity of wind and a greater rainfall have been registered at the head than at the mouth of the gulf, and intermediate values at the midway station of Nowanár.

The scientific value of the tidal observations will be greatly increased by the contemporaneous observations of the barometric pressure, the velocity and direction of wind, and the amount of rainfall.

Lights of the Gulf of Cutch.

The following is extracted from the List of Light Houses and Light Vessels in British India published by the Marine Survey Department:

Mándvi.

"S.W. bastion of the fort, latitude N. 22° 49′ 41″ longitude E. 69° 20′ 19″, a white fixed light, visible at 18 miles in clear weather, the arc of illumination being 180° and facing South-west; it is a white masonry tower above the fort wall, 115 feet above high-water, the height of building from base to vane being 56 feet. It is a catadioptric of 4th order, and was erected in 1873. Constructed and maintained by His Highness the Ráo of Cutch.

Tuna.

"At the edge of the mangrove swamp, South of Tekra island, latitude N. 22° 55′ 30″, longitude E. 70° 7′ 5″, a white fixed light visible at 6 miles in clear weather, of stone construction, 17 feet above high water, the height of building from base to vane being 23 feet, the character of the apparatus being a common lantern. It was erected on the 5th September 1878, and is maintained at the expense of the Ráo of Cutch.

Rojhi.

"On Rojhi temple, N.E. part of Rojhi island, at the mouth of Navánagar creek, latitude N. 22° 32′ 50″, longitude E. 70° 1′ 30″, a white fixed light visible at 7 miles in clear weather, the arc of illumination being 120°, or between the bearings of S.E. by E. $\frac{1}{4}$ E. round by the south to S.W. by W. $\frac{1}{4}$ W.; it is on a white round tower, 42 feet above high water. The height of the building from base to vane is 50 feet, the character of the apparatus being 3 common kerosine lamps. It was erected in 1867 by His Highness the Jám of Navánagar.

Bet or Bate.

"The highest and nearly the central part of Sainia island, latitude N. 22° 29′ 0″, longitude E. 68° 57′ 0″, a white fixed light visible at 12 miles in clear weather; the arc of illumination is 180°; it is on a white masonry stone tower, 35 feet above high water. The height of building from base to vane is 18 feet. It is a catadioptric 4th order light, and was erected, in 1876, at the cost of His Highness the Gáikwár, and is intended as a guide to the harbour and for vessels crossing the mouth of the Gulf of Cutch.

Dwárka.

"On the cliffs of the mainland West of the town, 350 feet within the high-water line, and close to the Stanhope column, latitude N. 22° 14′ 0″, longitude 68° 57′ 0″, a white fixed light visible at 6 or 7 miles in clear weather; the arc of illumination is 180°; the nature of construction is a white square stone tower, 70 feet above high water. The height of building from base to vane is 25 feet; the character of apparatus is 3 kerosine lamps; it was erected, in 1866, to prevent native craft running on the head-land, and also serves as a guide for anchoring in the small bay opposite Dwárka. A new catadioptric light of the 4th order will shortly be exhibited."

Assar Pir or Tomb.

"About 23 miles N.N.E. of Sainia island and 7 miles West of Mándvi, may be called the north boundary of the gulf; and it is in the direct line between Sainia island (the south boundary of the gulf) and Nanáo hill in Cutch, the principal land-mark in that province. Assar is a Mahomedan tomb, situated on the crest of the sand-hills close to the sea; its dome is at an elevation of 113 feet, and may be seen sometimes 12 miles off. To the S.W. of this place, rocky ground extends 3 miles

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with over-falls from 9 to 3 fathoms, and it should not be approached within $3\frac{1}{2}$ miles; the Mándvi light should not be brought to bear to the Southward of E. by N. $\frac{1}{2}$ N.

Mir Tamásha.

"Another tomb stands midway from Assar to Mándvi, and is 100 feet above the sea; the little creek to the East abruptly terminates the high sand-hill of Mir Tamásha, thus forming a steep sandy bluff, which on moonlight nights was formerly seen almost as soon as the old Mándvi light.

"Vessels bound to Mándvi should make this coast with Nanáo hill in a line with or to the left of Assar, bearing about N.N.E., that being the mark for clearing the West end of Ranwára shoals, which have patches of 3 and 5 fathoms rocky ground, at the distances of 6 and 7 miles to the South of Assar. Mándvi light may be steered for, when bearing E.N.E. but should be kept on the port bow, as the anchorage for large ships is $2\frac{1}{2}$ miles South of it.

Ranwára Shoal.

"From the shoalest part of the Ranwára the light-house bears from North to N. by E., and is $7\frac{1}{4}$ miles off. This patch, on which are always heavy breakers, is about $1\frac{1}{2}$ miles long East and West, and about half a mile broad; the bottom is sand, shells, and rock, and the least water 2 feet. The foul ground of the Ranwára covers an extent of 10 miles from East to West, and no large ship should approach Mándvi from seaward when the light bears between N.E. by E. and N. by W., until she is inside the Ranwára. In the daytime, the tomb called Ráwal Pir, 2 miles East of Mándvi fort, when *on with* Nanáo hill, is a safe mark for clearing the East end of Ranwára shoals.

Cutch Mándvi.

"This town in latitude 22° 49′ N., longitude 69° 20′ E., the most important commercial town in the gulf, situated nearly $3\frac{1}{2}$ miles to the East of Mir Tamásha, is a large walled town, of nearly square form, flanked with bastions, and was in its day a strong place. The S. W. bastion is highest, and on it the light-house is built, about 20 feet above the parapet, and 83 feet above high-water mark. The Ráo's palace (no longer used as such, but sometimes considerately given up by His Highness the Ráo as a rest-house[1] for British officers and their families) is a large flat-roofed building, and stands about 100 yards to the East of it. The sea-gate is near the S.E. angle of the fort, from which the narrow channel of the creek Rukmávati (which skirts the East side of the town) affording a passage for small boats only at high water, is distant rather more than a cable's length.

"To the East and to North of the town the creek runs inland, but it is merely the bed of a water-course, with a standing pool here and there except during the periodical rains and the night spring tides of the fine season. The creek's mouth is obstructed by sandbanks, which change with the least change of wind and consequent swell, although nearly dry at low water. Small boats can enter soon after the flood has made, and coasting craft of moderate burthen soon after half-flood. Freshets from the interior during the rainy season have an excellent scouring effect upon the fair channel of Mándvi creek (Rukmávati), but the first subsequent sea-breeze spreads the choking sandbanks again. Mándvi is a very opulent and busy port; its merchants trade by land and river with Márwár, Sind, Káthiáwár, &c., and by sea with Bombay and nearly all ports of western Hindustán, Persian Gulf, Maskat, the Red Sea, Gulf of Aden, and east coast of Africa (principally Berbereh and Zanzibár), and sometimes, but rarely, the Mozambique channel. From Bombay are imported the usual European goods and refreshments consumed by the British troops in Cutch, and a large quantity of English thread, with

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[1] There is now a good travellers' bungalow at Seráia.

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which the Mándvi cloth (rather famed for its quality) is woven. The imports from Africa are ivory, rhinoceros hides and horns, cocoanuts, and betelnuts; a gum called *chandrus*, used in dyeing and varnishing; at times, seeds, as jowári, mung, and til; gold in dust and ingots, dollars and venetians. Of late years also a cheap coarse and strong American cotton cloth (hence called Mirikáni by the Cutchis) has been much imported, obtained from American vessels at Zanzibár, and highly prized for its durability as a wearing apparel by the natives of Cutch. The exports from Mándvi consist of cotton, cotton cloths (all woven as above with English thread), and brass in wire and rods.

"The cloth-yard measure used is the *gaj*, of a trifle over 33½ English inches, and there are 24 *tasu* to one *gaj*. The current coin of Cutch is the *kori*, 404 of which (as established some years since by the British Government) go to one hundred Bombay rupees; this exchange, however, is not recognized by the native merchants, by whom the trade is calculated in dollars (reals) and venetians (either Maghrebi or Sitruni). British authority in Cutch is represented by the Political Agent or Resident at Bhuj, who has also a marine residence by Seráia village on the east of Mándvi creek, where a flag-staff will be seen.

People.

"The population of Mándvi comprises Vániás and Bhátiás, bound by their religion not to take the life of the smallest creature; they pay a tax to the Ráo, in consideration of which their feelings are respected, and peacocks and pigeons (so numerous in and around the towns) are forbidden to be killed. The crews of the fleet of boats which trade with Africa and Arabia are sometimes Musalmáns, but principally Hindus. As sailors they are bold and skilful, the Rajputs notedly so; their *muálims* (the pilots of Cutch) are a race deservedly famous for skill and daring; many of them have quadrants and nautical tables, and can determine the latitude by sun and pole-star, and their longitude by dead reckoning.

"Some of the Cutch boats (called Kotiya) are large, well built, and decked, and carry a pair or two of carronades. They sail for Africa about the beginning of October, and return just before or with the S. W. monsoon. The late arrivals, finding generally too much swell in Mándvi roads, and surf on the bar, have to run over to the sheltered anchorage at Chákha, and despatching thence much of their cargoes by small boats to Mándvi, when lightened, take advantage of the first lull of the monsoon (for which they have to wait only a few days), and come bumping over the bar into Mándvi creek at high water.

Mándvi Creek.

"Boats drawing more than 9 feet water can seldom enter the creek at the most favourable season (October to February) when the rains from the hilly country have scoured out a deep channel. With the West winds the entrance begins to get choked up with sand, until, in May, a boat drawing 7 or 8 feet has to bump over the bar to get into the creek; and, in the latter part of May and beginning of June, frequently a dozen vessels are rendered useless by this operation, and as many more have to undergo a thorough repair. These boats coming from Bombay and distant parts, knowing that it is about high water, never give a thought as to the depth of water; but running in carelessly, take the ground, and bump till the receding tide leaves them high and dry, when their goods are landed in carts; and the vessel, being lightened, floats in at next high tide.

Tides.

"It is high water on full and change of moon at Mándvi at 0h. 15m. This time is sometimes retarded several minutes during West, and accelerated during East winds. The rise and fall is, at ordinary springs, 15 feet, and sometimes at high springs 17 feet. At neaps it is 9 or 10 feet.

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"In navigating the Gulf of Cutch, vessels should always make an allowance for the tides, which run 4 or 5 miles an hour at springs, and 3 at neaps, East and West, between Chinri reef to the South, and Ranwára shoals to the North. All across the mouth of the gulf the bottom is very uneven, and the rapid tides cause a very confused breaking sea, even in a depth of 30 fathoms.

"The tides at the anchorage off Mándvi, in 3 to 5 fathoms water, run at the rate of 3 knots an hour on the springs, and at neaps less than 2 knots; further out from the shore they increase in strength, and on the Ranwára shoal, attain a velocity of 5 knots on the springs and 3 at neaps. This strength of tide is maintained between that shoal and the reefs of Chákha, Noru, and Bida to the Southward, and cause a heavy deceiving break, in many places, where deep and shallow water are contiguous. Between Mándvi and Tamásha, the soundings gradually increase off shore to about 10 fathoms at 4 miles distance, outside of that, and to the West towards Assar, and a little beyond it, there are overfalls from 5 to 10, and in some places to 20 fathoms. The tides running with great velocity over these rocky patches cause a heavy rippling and break, which is very deceiving to a stranger.

Anchorage.

"There is good anchorage for ships, in 3 to 5 fathoms at low water clay bottom, from 1½ to 2½ miles due South of the fort; and nearer the shore for small steamers, in 2 fathoms, sand and mud, with the light-house N. by W., and the Political Agent's flag-staff (on the East side of the creek, to the right of the large banyan tree), bearing N.E. by N. There is a shoal rocky patch bearing S.W. ½ S. rather more than 2 miles from the light-house, having 11 feet only at low springs.

Ráwal Pi

"Ráwal Pir is a white tomb, 70 feet above the sea, in a clump of trees on sand-hills, 2½ miles E.S.E. from Mándvi fort. This tomb *on with* Nanáo hill clears the East end of the Ranwára shoals. Between Ráwal Pir and the Mándvi fort, by the village of Seráia, stands the marine residence of the Political Agent in Cutch, with a flag-staff in front. Modva point is 8 miles Eastward of Mándvi. The intermediate shore is fronted with sand-hills, 30 and 40 feet high. The point itself is a high sand-bluff, and off it there is a ledge of rocks dry at low water, which are deep-to, having 3 and 4 fathoms close to them. Inside the point is an extensive backwater, which runs back to within 2 miles of Ráwal Pir, but is only entirely flooded at very high spring tides, and at high water in the S.W. monsoon. Behind Modva point there is excellent shelter for small vessels hauled up in the S.W. monsoon, preferable to Mándvi creek, as there is a depth of more than 2 fathoms on the bar at high water springs, and it is protected from West winds. The ledge of rocks before mentioned extends nearly a mile to the East of these. To the S.W. of the bluff, the sand dries out for nearly a mile from the shore when the tide is out.

"The coast-line to the E. of Modva recedes from the low water line from 2 to 3 miles, but there are long thin strips of sand from 5 to 10 feet above high-water mark, fronting the sea, which are from half a mile to one mile distant from the sea at low water; between these and the mainland is an extensive swamp, covered with mangroves, and intersected with numerous small creeks, where boats go to cut firewood.

Navinár, or Nawinar Point.

"This point, at 20 miles East of Mándvi, consists of 2 or 3 thin strips of sand, the highest part of which is not 10 feet above high-water mark. The mainland here recedes 4 miles from the point, and the intermediate space is a vast swamp, covered in places with mangrove bushes, through

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which runs up the Nawinár creek and many other small ones. Nawinár point is deep-to having 11 and 12 fathoms South of it less than three-quarters of a mile off. To the Eastward of Nawinár point there is shelter for a few small vessels during West winds, in 2 to 3 fathoms with the Point W.S.W., out of the strength of the tide.

Sonar Darri Shoal.

" This sand bank between Modva and Nawinár consists of detached sands, which are dry at low water, with deep water between them. The West ones are 4½ miles E.S.E. of Modva point, and the East sands lie 6½ miles W. by S. of Nawinár point. The South sides of these banks are deep-to having 12 fathoms at 2 or 3 cables off. A vessel ought not to shoal under 15 fathoms here. During the first half flood, and after half ebb, the shoals may be distinguished by the rippling of the water. And, indeed, they may always be distinguished from the mast-head by the discoloured water on them. These shoals bear E.S.E., and are 12 miles distant from the anchorage in Mándvi roads, they extend fully 3 miles off the nearest shore.

Mundra Creek.

" Its mouth (between mangrove bushes) bears N.N.E., 3 miles from Nawinár point, and it runs up to a bandar-house N.N.W. for little more than 1 mile. The house is perfectly isolated at high water springs, the tide flowing a mile to the North of it. (There is now a very fair road from the bandar to the town). The bandar-house is 3½ miles N. by E. of Nawinár point.

Mundra Fort.

" This fort, situated 2½ miles Northward of the bandar-house, has a white mosque, distinguishable a good way off, and a grove of high cocoanut trees, half a mile to the West of it.

Mundra Shoals.

" At 3 miles to East of Nawinár point there is the South-west end of a 2-fathom bank, lying N.E. and S.W., 2½ miles long and 3 or 4 cables broad, and N.E. of this again there is a 3-fathom bank, 2 miles long lying N.N.E. Between the South end of the former shoal and the shore low-water mark (which is here 4 miles from the mainland), there is a small patch having only 7 feet on it. On account of these banks off Mundra, a vessel should not shoal under 10 fathoms in going Eastward, Bhadreshvar Temple bears N.N.E., when she may stand in to 5 fathoms, bottom all mud.

The Coast

" The Cutch coast from Mundra to the Nukti or Tuna creek entrance is nearly straight, about E. by N. ½ N., and the mud dries to nearly 4 miles off the shore by Mundra, and 2 miles off towards Tuna. The soundings are very regular, and the bottom is mud. All along the Cutch coast water-courses empty themselves into the sea during the rains, and the whole coast from Modva to Tuna is very low, with cocoanut trees by all the towns to the Westward of *Bhadreshvar Temple*, which is 11 miles E.N.E. of Mundra, and has a small white dome which points it out very well, and may be seen 9 or 10 miles from a vessel's deck. There is a grove of trees 1¼ miles South of the temple, and Bhadreshvar fort is a little West of it. Tuna fort stands some distance inland, about a dozen miles E.N.E. from Bhadreshvar fort; the intermediate shore is quite low and sandy, with two or three little villages.

Nukti Creek.

" This called also *Tuna creek*, as one branch of it leads up to Tuna bandar, is 13 miles East of Bhadreshvar; its West point is very low, covered with mangrove bushes, and nearly overflowed at high water. The only natural object that marks the entrance of Nukti creek is a mud island, covered with trees, 15 to 20 feet high, called *Tekra* by the natives; it is about three-quarters of a mile long, N.W. and S.E., and about a mile to the North of Tuna sandy point, from which Tuna bandar bears about

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N.W., distant 4 miles. Pilots are required to take small vessels up to the bandar.

Tuna Tekra.

"A Light-house recently erected by His Highness the Ráo is at the edge of the mangrove swamp on the South of Tekra, in latitude 22° $55\frac{1}{2}'$ N., longitude 70° 7′ E., and shows a small light 17 feet above high-water level.

"Boats bound from Mándvi to Jodiya, on the opposite side of the gulf, in the N.E. monsoon, run along shore and sight the Tekra before they branch off to the Southward. Jodiya bandar bears about S.S.E. $\frac{1}{2}$ E., distant $15\frac{1}{2}$ miles from Tekra.

Tuna Bandar.

"This place lies 4 miles N.W. from Tekra, and though it is the sea-port of the large town of *Anjár*, is an insignificant place, with difficulty can boats of 50 tons burden get there at high spring tides, as it is up a small creek, not 30 yards wide, branching away from the Nukti. The creek, but for posts that are erected on each side of its entrance, would not be discernible. The flood-tide rushes by the small mouth of this creek to the Northward with a velocity of 4 miles an hour. A pilot of the place would be required to take the vessel in.

The Ran of Cutch.

"In the N.E. monsoon, from November to February, the Ran is dry, and traversable by men and camels, but the fine sand of the surface, agitated by the N.E. winds, blinds the traveller. In the Westerly monsoon, the sea water is propelled by the wind many miles to the Eastward, and the Ran has then the appearance of a great inland sea, and quite impassable for travellers. This vast sheet of water, in the vicinity of the three large creeks which drain it (the Nukti, the Kundlo, and the Hansthal) is subject to the regular tides, but the rise and fall inside is not of any extent, though the Hansthal, from the great height of the internal waters, attains a velocity of 6 to 7 miles an hour at its mouth in ebbing. When in January 1852 the rise and fall of the gulf water off the mouth of the creeks was 15 feet, it was only 5 or 6 feet to the South of Jangi, some 15 miles from Hansthal mouth. Captain Baird, R.E., subsequently found the extreme range of tide at Hansthal to be 20 feet. This difference of level of course renders the ebb-tide, in the Hansthal deep channel, to be of longer duration, and the flood shorter, or respectively, about 8 and 4 hours.

The Hálár Coast.

"*The North shore of Káthiáwár* which forms the South side of the Gulf of Cutch is under a different sovereign,—the Jám of Navánagar,—whose territory commences with all the banks and creeks which lie South and East of the Hansthal, and extends to the great Barál reef, or 50 miles Westward of Navánagar. The Halár coast has no high land; but the Barda hills, in the interior of Káthiáwár, are sometimes visible from this South side of the Gulf in clear weather.

Mangra Reef.

"This reef to the North-west of Jodiya has its West end at the distance of 8 miles from the fort, and its East end at $6\frac{1}{2}$ miles. From it the mouth of the Hansthal bears N.E. by N., nearly 10 miles off, and the mud uncovers at low water out to a line between them. The East end of Mangra reef bears S.E. $\frac{3}{4}$ S., about 12 miles from Tuna Tekra. The West end of the reef is deep-to, having 5 and 6 fathoms close to it. And at $\frac{3}{4}$ mile from this West extreme there is a heap of sand and shells, which is the first part that dries (then showing distinctly the position of the reef), and it lies with the N.W. bastion of Jodiya and the Darbár-house in a line nearly. The breadth of the Mangra reef is one mile at the West end and $\frac{1}{2}$ mile at the East; there is a deep channel along the South side of it, and a vessel may anchor and be sheltered from strong

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N.E. winds with the sand-heap bearing from North to N.N.E. 2 miles off, N. in 3 fathoms, at low water, muddy bottom, with Jodiya fort E.S.E.

Jodiya Fort.

"This fort on the South shore of the gulf bears S.E. by S. 21 miles from Tuna fort. The N.W. bastion which is about 80 feet above sea, and the Darbár house (300 yards S.E. of the former), are high and conspicuous. And outside the fort, nearly a mile to the Southward, there is a grove of high trees. These three marks point out the place unmistakeably, and may be seen in clear weather 10 to 12 miles off from a vessel's deck. Jodiya N.W. point is of low sand, and bears W.N.W. $3\frac{1}{2}$ miles from the fort; the bandar is more than 2 miles to the N.W. of the fort, and $1\frac{1}{2}$ miles to the Eastward of the N.W. sandy point.

Jodiya Bandar House.

"The landing place for Jodiya stands N.W. $\frac{1}{2}$ N. $2\frac{1}{4}$ miles from the fort. The entrance of the creek (amongst mangroves) is with this house one mile distant and on with Jodiya trees. Boats coming from Mándvi to Jodiya keep along the Cutch coast, and sight the Tuna Tekra before they slant off to Jodiya, and run round the East end of Mangra reef, with the bandar house bearing South into Jodiya creek, but this cannot be done till after half-flood by boats drawing upwards of 7 feet water.

Tides.

"It is high water on full and change of moon at Jodiya bandar at 2h.; rise and fall of tide is 16 feet at ordinary springs, and 9 or 10 at neaps; but 18 or 19 feet at highest springs.

Báláchadi.

"This is a small village, bearing S.W. $7\frac{1}{2}$ miles from Jodiya fort: there is, at the distance of $\frac{3}{4}$ mile to the N. W. of the village, a small, round, conical hill, detached from the main, and insulated at high water, on the top of which is a Mahomedan Fakir's place, called Áku Pir, and $\frac{1}{2}$ mile S.W. of this, on the West of the village, is a range of rocky mounds 60 to 80 feet high, fronting the sea; they extend over half a mile of ground in a North and South direction, and constitute the sanatarium of the English residents from Rájkot; when tents are pitched there, they make an excellent land-mark. These tent-hills are insulated at high water springs. Between these hillocks and Áku Pir there is a small creek, off the mouth of which is a large rock dry at half-tide, and the mud and the rocks dry out at low water for $1\frac{1}{2}$ miles to the Westward. At the back of Báláchadi there is a range of hills about 100 feet high, which terminate rather abruptly to the South at $1\frac{1}{2}$ miles to the S.E. of the village.

Shoal Water.

"This extends for more than five miles to the west of Báláchadi, and the place is only approachable towards high water, and with a native pilot. The shore between it and Navánagar is fronted with mud and coral banks, and no vessel should go near it.

Navánagar, or Jámnagar.

"This is the largest and best fort in the gulf, at 18 miles to the S.W. of Jodiya; it is the capital of the independent principality, Hálár, which is ruled by the Jám of Navánagar. British authority is represented along the South side of the Gulf of Cutch, by the Political Agent in Kathiáwár, whose head-quarters are at Rájkot, about 50 miles to the S.E. of Navánagar. The fort is more than 7 miles to S. by E. of the anchorage off Navánagar. The Kota is a high, circular, turreted building on the West side of the fort, 182 feet above the mean sea-level, and from its whiteness, may be seen in clear days, when the refraction is great, at 20 miles distance, and commonly at 15 miles. Rather more than half a mile to the East of it stands the Darbár-house, a large building with a gable roof at either end, and half a mile to the N.W., outside the fort, is a look-out tower: all three are conspicuous objects. *Navánagar Kotha* is in latitude 22° 27′ N., longitude 70° 3′ E.

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Bedi.

"A little village and fort, where stands the bandar, or sea-port of Navánagar, is 2½ miles N.W. of the great fort. Boats can come up the creek to within ¾ mile of this little fort. The mouth of Bedi creek is about two miles from the anchorage off Navánagar and nearly one mile to the N.W. of Rojhi Temple; its West side is rocky, and the East side soft mud.

Rojhi.

"A little Hindu Temple with a flag-staff stands midway between the anchorage and Bedi fort.

Tides.

"High water at Rojhi, at full and change of moon, at 1h. 40m., rise and fall at high springs 18 feet, at ordinary springs 16, and at neaps 10 feet.

Anchorage.

"The anchorage of Navánagar is with Pirotan island just seen outside of the large mangrove island between it and Rojhi, and with Rojhi Temple bearing S. by W., or both the towers of Navánagar open to the left, or eastward of all Rojhi land, in 2 or 3 fathoms at low water well sheltered from the West winds, which prevail from February to October inclusive. The bottom is such very soft mud, that a vessel can safely anchor in her own draught of water; the entrance of the creek will bear from this anchorage S.W. by S. West of this anchorage half a mile there is a small *detached reef*, dry at low water, having a passage between it and the main reef. And 1½ miles N. by W. of the anchorage, there lies a 2-fathom rocky patch. The Darbár-house touching the East extreme of all Rojhi land is on the line of both these shoals.

Directions.

"In coming from the West a vessel passing one mile to North of the Pirotan reef, must stand on the East course, till all the high towers of Navánagar are seen (from aloft), to the left or Eastward of all Rojhi rocky land; this is to avoid a 2-fathom patch lying 5 miles Eastward of Pirotan.

"In coming from the N.E., Bedi fort should not be opened to the left of, or Eastward of all Rojhi land, for on this line and all East of it, the ground is rocky at the distance of 1½ miles from the above mentioned anchorage, so that Rojhi Temple bearing from S. ½ W. to S.S. W. ½ W., are the limits between which to anchor.

Pirotan Trees.

"Extending a long way to the North and West of the entrance of Bedi creek, there is a mangrove swamp, with a sand-bank on its N.E. face, the North extreme of which will bear about West from the anchorage above described. To the West of this sand, and at the distance of 6 miles N.W. by W. of Rojhi, there is a detached mangrove island, whose trees are 20 to 30 feet above high water, the highest being at the N.E. end. This is called Pirotan, an excellent land mark in making this coast, as the trees, like those of the Tekra on the Cutch coast, are not allowed to be cut down.

Soundings.

"Off the Pirotan a vessel ought not to shoal under 20 fathoms, till its high trees bear to the Westward of South. A coral reef steep-to and dry at low water extends off this island one mile to N.E and ¾ mile to S.W.; the west side of Pirotan forms the East side of the Sarmat Khári entrance, and when the reefs are dry, a vessel may conveniently anchor, to get shelter from N.E. winds, in the mouth of the Sarmat, with the Pirotan trees bearing N.E. by E. in 5 or 6 fathoms, muddy bottom. Pirotan high trees are in latitude 22° 37′ N., longitude 69° 57′E.

"Eastward of a line from Navánagar, on the South shore of the gulf to the Tuna Tekra on the Cutch coast, there was in 1852 at low water nowhere more than 10 fathoms water across the gulf, whereas the charts of 1821 represent the head of the gulf as much deeper, and there can be no doubt it is gradually filling up. Eastward of a line from Pirotan to Bhadreshvar, there is nowhere more than 20 fathoms. Here it may be useful to the navigator (when going direct from Mándvi to Navánagar) to know that Pirotan bears S.E. by E. about 15 miles from Navánagar point on the Cutch coast.

The Hálár Coast.

"From Navánagar to the west for more than 30 miles, the mainland of Hálár recedes from 4 to 6 miles within the sea face of the reefs which bound this coast, and it has no distinguishable objects, with the exception of two or three hills, which are too far off to set as land-marks; but clumps of mangrove trees on the reefs form excellent guides; they are not allowed to be cut down, and are named by the boatmen Pirotan, Dera, Nurria, Karumba, and Dhuni. Dera differs from the rest of these marks in being a sand-hill, which from a distance looks like a tent, when the sun shines on it. The Badra hills are frequently visible from this side of the gulf; and, off Rojhi, they may be seen on a clear day (a distance of 46 miles).

Sarmat.

"South-west of the Pirotan lies the entrance to the Sarmat-khári, between reefs, a little more than ¾ mile wide, and at the same distance within the entrance there are some rocky patches, which render it unsafe to run far in without a pilot, but a vessel may anchor from ¼ mile to ½ mile to S.W. of the Pirotan reef, in 5 fathoms mud, with the high trees bearing N.E. to E.N.E., and well sheltered against strong N. Easters. But it will not be prudent to run in there till a couple of hours after high water, when the edge of the reef will be seen quite dry.

Dera Sand.

"This is a range of low sand-hills, 6 miles S.W. of the Pirotan. (The name is applied to the coral reef surrounding it, or the whole space included between the Sarmat and the Sika inlets). The N. W. end of Dera sand is bluff, about 15 feet high, and off it are a few scattered stunted mangroves. To the eastward these trees are thicker, and there are two or three single conspicuous trees at the distance of from 1 to 1½ miles east of the bluff. The reef extends off Dera sand-hill nearly 1½ miles to N.W., and Goos reef is to the S.W. of it.

Sika Inlet.

"Is 2 miles W.S.W. of Dera, and is navigable for only 4 or 5 miles at low water, but at high water large boats can pass through channels amongst the mangrove bushes, almost in a direct line to Rojhi, and hence to Bedi.

Nurira.

"A clump of trees with a sand before it stands distant 8 miles about W.S.W. from Dera sand-bluff. The reef extends off it 1½ miles to northward, where the rocks are highest, and 2 miles to N.E. A mangrove swamp joins Nurira clump with the mainland. In the centre of the bay, between it and the Dera, lies the Goos reef more than 3 miles long east and west, and 2 miles broad. At ½ mile from its north side there is a long sand that dries before the reef itself, and shows well. On its south and west sides there are deep water channels, which, as well as that along its east side, bear the name of Sika-Khári. These channels are used by native vessels when it is blowing very fresh; they thus avoid the heavy sea outside. The north edge of Goos reef is on the line from Dera bluff to Nurira.

Soundings.

"A vessel should not, in working, come under 12 fathoms between Nurira and Pirotan, and not under 15 fathoms when northward of the former, and between it and Kárumba. There is nowhere so much as 25 fathoms at low water to the eastward of a line from Dera in Káthiáwár, to Mandra in Cutch. There are rocky patches of 7 and 8 fathoms in the middle of the gulf, midway in the track of vessels from Mándvi to Saláya.

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Kárumba.

"This land-mark is a mangrove island, 4 miles long, east and west, and a little less north and south, with a clump of high trees on its north edge, which bears from Nurira W. $\frac{3}{4}$ S. 6 miles. Northward of these trees the reef dries $1\frac{1}{2}$ miles off, forming a projecting point, from which the line of reef on the one side trends to S.W. for 4 miles to the entrance of Saláya Khádi, and on the other takes a S.E. direction for $2\frac{1}{2}$ miles to another channel that leads round Kárumba island up to Saláya: the mouth of this latter channel is nearly midway on the line from Nurira to Kárumba; it is very deep, but narrow, and at 3 miles up is only navigable at high water by boats standing over the reefs and the mud-flats. A vessel may run in for $\frac{1}{2}$ mile at low water when the reefs are visible, and be well sheltered from westerly winds.

"The point of rocks north of Kárumba is deep-to, and a vessel should not come under 20 fathoms; but with the trees bearing S.E. a vessel can come in to 15 fathoms, mud; and with them E.S.E. into 7 fathoms. Between the trees of Kárumba and those of Chákha island, there is nowhere to the south more than 10 fathoms at low water, except in the mouth of Saláya creek.

Saláya or Saláya Inlet.

"This port, the entrance to which lies between Kárumba and Dhuni trees, may, at no very remote day, become the Liverpool of Káthiáwár. Saláya is already an important native port, being the bandar of Khambhália, a large town about 6 miles inland, and its position, as regards the cotton fields of the peninsula, together with the great depth of water in the inlet, and the perfect shelter it affords, mark it out as deserving the attention of European merchants. The fact of its belonging to a Native Chief, who has no one to advise him on maritime matters, hinders the development of trade at Saláya inlet, which has as great a depth at low water as the Mersey of Liverpool can show at high water in its entrance. Saláya Khádi mouth is in latitude 22° 28' N., longitude 69° 32' E.

The Entrance.

"From Kárumba trees a thin low strip of sand, with mangroves on the sea-side, runs to W.S.W. $2\frac{1}{2}$ miles; its West end is higher, and has bushes on it, the tops of which are 10 feet above high-water mark. The rocks dry a little more than a mile West of this sand, and a vessel will find excellent shelter in this entrance of Saláya inlet, or Khádi, from N.-Easters, by anchoring 2 or 3 cables length from the reef, in 6 to 10 fathoms, mud, with this nearest point of the sand E. by N., after Kárumba trees have just passed behind the North point of high-sand; and with a large banyan tree on with a little conical hill ($11\frac{1}{2}$ miles inland), bearing S.S.E. $\frac{1}{2}$ E. These last are the leading marks into Saláya creek. Towards low water the reefs are well defined, and at any time the mast-head look-out man will discern them, when within 2 or 3 cables length.

Dhuni.

"This is a tuft of trees on sand, 6 miles W.S.W. of Kárumba, forming the West point of Saláya Khádi, which runs up 9 miles to Saláya bandar. The principal town to which goods are carried by land, is Khambália, which is 6 miles Southward of Saláya. The creek is known by both names, Saláya and Khambhália; it has not yet been surveyed on the large scale, and a vessel had better take a pilot at Cutch-Mándvi, if bound to Saláya.

Chákha or Sahuka.

"This is a little island covered with trees, the North end of which is in latitude 22° 32' N., longitude 69° 23' E., 9 miles N.W. of Dhuni trees: and hence to Vománi, the North point of Okhámandal, this end of the gulf has nothing but reefs and islands, with good channels amongst them, which are most useful to coasting craft during the prevalence of strong breezes, when there is a heavy swell outside. Chákha is the N.E.

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of four islands on the Great Barál, or Chákha reef, the North face of which is 10 miles in length. The N.E. end of the reef forms in a full semi-circle, with a radius of 1½ miles round Chákha island; after the first quarter-ebb, the rocks at its margin begin to show themselves. Chákha bears about S. by E. from Mándvi.

Bubasir Rock. "This danger, on which a small post used to be visible, lying rather less than a mile from the East edge of the above reef, bears S.E. by E. 2¼ miles from Chákha trees.

Anchorage. "To the East and S.E. of Chákha trees there is good shelter for ships of any size against Westerly winds; the beacon on Bubasir rock formerly made navigation easy, and it should be re-erected. A good anchorage is in 5 fathoms, mud, at low-water about ½ mile S.W. of the rock; but a vessel only taking shelter for a single tide, may anchor to the North of it in 8 or 9 fathoms, mud, just on the edge of the shoal soundings, with Bubasir beacon S. by W., and Chákha trees West.

"This anchorage on the East of Chákha for the S.W. monsoon is worth knowing. A vessel disabled between Dwárka and Kurrachee, and unable to claw off the coast, need not now, with the latest charts on board, have any fear to seek shelter in the Gulf of Cutch. Rain seldom falls hereabouts, and the shore is not so completely hidden as off Bombay. In the daytime the towns and trees between Dwárka and Bet island will be discerned from aloft, and a vessel can run in either to North or South of Beka shoal. After passing Chinri reef, she would be unable, with a S.W. wind to haul up to the Southward to clear Hanumán-dánda and fetch the anchorage on the East side of Bet island without tacking; therefore, we recommend her to run for the sheltered anchorage behind Chákha. To do this, she must stand to the East along the North face of the Barál reef. Care should be taken, in approaching this reef at high-water, to keep a good look-out for the trees on Noru and Chákha, which should not be approached nearer than 3 miles till the vessel is off the latter, when she should haul up to the S.E., when Chákha trees bear South and then the water will soon become smooth, and she may anchor in 8 or 10 fathoms, mud, about one mile to the East of Bubasir rock, and 3 or 3½ miles from Chákha, with the trees bearing W.N.W.; in this position the ebb sets to N.W. and the flood to S.E.

Shelter. Large native vessels *(Kotiyás,* often called *Dhows)* arriving from the Malabár and African coasts, after the commencement of the S. W. monsoon, seek shelter to leeward of Chákha, and there discharge the bulk of their cargo into smaller boats, which, watching their opportunity, bring the goods over to Cutch-Mándvi; the larger vessels follow at spring-tides, and boldly run into Mándvi creek at high-water in the daytime, when the tides are highest.

Soundings. "Between Bubasir and the Dhuni fringing reef (the latter is 5 miles S.E. of the former) the bottom is generally mud, though a few casts of hard ground were found, but the water is not deep. In working to the Westward amongst the reefs and islands, the native boatmen usually wait till the falling tide makes the banks apparent. The most minute description of the channels amongst these islands would not be sufficient for the guidance of a large vessel, which should take a native pilot, as the tides are so strong in some places; and an intimate knowledge of their set is necessary, as the eddies make a vessel unmanageable in light winds. The set of the ebb stream during the first hour of ebb, when it runs out over the reef, is of course very different from the direction it takes after half-ebb, when it is confined within narrow, deep channels.

Barál Reef. "This vast coral reef surrounding the islands of Chákha, Noru, Bida, and Chusra, is completely covered at high-water of spring-tides, the

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islands only being then visible. Its North face is very deep-to, the soundings very irregular from 20 to 36 fathoms, and the tide rushes by with a velocity of 4 to 6 knots. Off its N.E. end the water is shoaler, 15 to 19 fathoms, and beyond this there is a bank, on which are found rocky patches of 7 and 8 fathoms: there is no danger on this bank which extends more than 10 miles to N.E. of Chákha, although the shoal water and uneven bottom cause heavy ripplings and breaks, the rush of tide being so strong.

"**Noru** is a large, low, mangrove island, on the Great Barál reef, situated 2½ miles to West of Chákha trees; it is nearly 3 miles in length East and West; its North face is fronted with sand, at the East end of which are the highest trees, about 25 feet above high-water. On the North of Noru the Barál reef is deeply indented, and the soundings are mostly mud near the reef in the two angles, where small coasters, when working tide-work with Westerly winds, can at low-water find anchorage, where they wait for the next ebb. Chákha, the N.E. island, is described in the preceding pages.

"**Bida** is a mangrove island nearly 2 miles across; its West face is fronted with sand, the North end of which is highest, being nearly 20 feet above high-water; it lies 3 miles S.W. of Noru, or about half-way towards Chusra, and about 5 miles to E. by S. of Pága sand.

"**Chusra,** a small rocky islet, with a clump of trees on its North end, stands 2½ miles S.W. of Bida, and marks the South extreme of the Barál reef, as it is only 3 cables length within the South point of the rocks. Chusra trees are a most excellent mark for navigating these inner channels.

"**The N. W. extreme** of Barál reef, which extends nearly 6 miles to the West of Noru highest trees, and is 7½ miles to North of Chusra, has the rocks at its edge piled up in three places, which are dry in rather more than one hour after high-water of spring-tides, but at neaps are scarcely covered at all. A beacon on that point would be a valuable mark, that vessels might avail themselves of the shelter against N.E. winds afforded in a snug anchorage with a depth of 4 or 5 fathoms, muddy bottom, 3 or 4 cables length to the West of the fringing reef, the bearings for which are as follows:

Anchorage.

"Chákha trees (seen from aloft) just touching the North sandy face of Noru islands, bearing East, and Chusra trees bearing S. by E. ¼ E. (on with Quoin hill on the mainland, which is 15 miles distant, and only seen above the deck, and in clear weather). This is a good anchorage, in 4 or 5 fathoms, mud, where no ebb stream is felt, and very little flood. To the South of it there are patches of shoal water; and a bank of sand and rock, with overfalls from 5 to 7 fathoms, extends to the Westward of Chinri reef, and Southward to the Pága reef; over this bank the soundings are everywhere alike, ranging between 5 and 10 fathoms; but in the centre there is a deeper gut, having 12 to 15 fathoms; the bearings of the land must then be the sole guide, as the soundings, except when in the centre, will not indicate a vessel's position; and, at spring-tides, the ripplings and breaking water frequently alarm a stranger.

Pága or Turtle Reef.

"This reef lies 3 miles to the N.W. of Chusra trees, and to the West of Bida, allowing a passage one mile broad between it and Barál reef. Its greatest length is nearly 4 miles S.E. and N.W. On its West side there is a bank of sand, which is only completely covered at high water springs, and forms a good mark; this sand-heap lies 3 miles to the Eastward of the East end of Bet island. Okhámandal table-land S.E. bluff (which is 8 miles South of Poshitara), seen between the Brothers,

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or Sahu islands, is the mark which will keep a vessel clear of the S.E. extreme of the Pága reef, and will lead in clear to those islands. The highest peak of the Barda hills on with, or one degree to the left of the highest part of Ajár island (seen from aloft), clears the N.E. side of Pága reef. The North lip of the reef (which never shows above water) lies 3½ miles to the East of the Chinri sands, and bears about W.S.W. from the anchorage described, as available during N.-Easters, at the N.W. extreme of Barál reef.

Chinri Reef.

"This reef, about 2 miles north of Bet island, has also a sand-heap only covered at high springs, on its South side, which bears N.W. by W. ½ W., 4½ miles from Pága sand; the reef that dries extends more than 1 mile and shoal water nearly 2 miles to the North of the sand; the east extreme of this shoal water bears E.N.E., nearly 2 miles distant from the sand. To the South of Chinri sand the reef is deep-to, and there is a passage, one mile wide, between it and the reefs of Bet island; and between it and Sainia island, the water is shoal, with overfalls from 3 to 8 fathoms.

Beyt, Bet* or Bate Island (properly Shankhodvár).

"The East end, composed of sand-hills and bushes, and 3 miles to the West of Pága sand, is called Hanumán point, after a temple of that name, situated about ½ mile within the point. The reef to the North of this point is called Hanumán-dánda, and extends Westward for 1⅓ mile to the N.E. of the sand-hills that border the N. side of Bet. The island from N.E. to S.W. measures 5 miles; but, being a narrow and crooked strip of land, is in its windings half as long again. Its S.W. half is rocky table-land, about 50 or 60 feet high. Temples in honour of Krishna abound; the population, principally Bráhmans, are mainly supported by pilgrims who resort here. When Bet fort was taken from the Vághers by a British force in 1859, some of the principal temples were blown up with the fort; before that time the island had 500 houses and 3000 inhabitants.

"Bet fort flag-staff is in latitude 22° 27½′ N., longitude 69° 5′ E.

Shelter at East end of Bet.

"A vessel, coming in along the South side of Chinri reef, must pass its sand-heap at one cable's distance, and stand to the Eastward, not letting Árámbhada Tower disappear behind Bet island, till Chusra trees just touch the right or South side of Pága sand, which bearings will lead her clear of Hanumán-dánda; then she may steer to the South-east with the latter marks on, gradually opening them as she hauls to the South and as the Kiu hills begin to appear to the left of the bushes on Hanumán point, when she may steer for those hills, keeping them just open to the South of the bushy point, or about S.W. by S. (according to tide, remembering that the ebb will force her to Westward against the Hanumán-dánda); and then anchor off the East end of Bet island as follows:

"Anchorage off the East end of Bet Island, well sheltered from Westerly gales, and approached as above, may be had in 5 or 6 fathoms, mud, rather more than half a mile from the shore, with Hanumán temple N.W. by W., the sandy extremes of Bet island, from S.W. by W. to N.N.W. (the Chinri sand being just shut out of sight by the latter bearing), where the ebb sets to the Northward, but the flood is scarcely perceptible. To the East of this anchorage the bottom is rocky, so it is well to anchor near the island, the water during Westerly winds being perfectly smooth.

Poshitara Bay.

"Between the sandy S.E. side of Bet island and the mainland of Okhámandal the passage is very shallow, having a bank in mid-channel

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[*] This word Bet simply means *island* in Káthiáwár.

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which is nearly dry at low tide. The water deepens towards the south extremity of the island, but the many sunken rocks make it unsafe for navigation without a pilot. *Poshitara point* is nearly 4 miles S.E. of the east end of Bet, and the town of Poshitara is on high ground nearly 2 miles S.W. of the point; there are two large banyan trees to the N.W. of the town, which are conspicuous objects. There is a sunken reef one mile to north of the point; and to the east of it, foul ground for nearly 2 miles. A sand-bank on this foul ground, called *Boria*, and only covered towards high-water, marks the east extreme; but a separate little reef lies to the northward, between which and Pága reef the fair channel is 1½ miles broad. Chusra trees, touching the north end of Ajár island, are the leading marks through this passage.

"When clear to the north of these Boria reefs the Kiu hills are a little open to north of Poshitara point. When clear to the east of them, the S.E. bluff of Okhámandal table-land is seen between the Brother islands.

The Brothers.

"These two islets, called by the natives *Shán*, are situated 2½ miles S.E. by S. of Poshitara point; the western one is largest, with a flat top, about 60 feet high; the other is a small conical islet. There is good anchorage at ½ mile east of the Brothers, and also on their west side in 6 to 10 fathoms, mud, and sheltered from all winds. Attention has lately been called to this *Poshitara harbour* as affording deep-water shelter for the largest ships, within half a mile of the mainland of Okhámandal. This territory belongs to His Highness the Gáikwár of Baroda.

MOUTH OF GULF OF CUTCH.

Saihia (Saiáni) Island.

"This rocky islet, in latitude 22° 29′ N., longitude 69° 4′ E., bounding the north side of the Bet inner harbour, has a sandy spit stretching off one mile to the N.W. There is a little tomb called Saiáni Pir in the centre of the island standing 40 feet above high-water level, and a lighthouse has recently been erected by its side which is the most useful mark hereabouts, and may be seen 9 or 10 miles from a ship's deck. *Gurur shoal* of sand and rock, on which there are various depths of water from 10 to 3½ fathoms, extends over a length of 10 miles N.E. and S.W., and has a sandy knoll, called *Beka*, just dry at lowest water of spring tides, on the N.E. end at 5 miles from the mainland; Bet cocoanut trees just to the right of Saiáni Pir, bearing S.E. ½ S., mark this little patch which dries at the lowest spring tides.

Soundings.

"The depth between the Gurur shoal and the shore reef varies from 12 to 20 fathoms; the bottom is sand and shells. The south and west parts of the Gurur are free from danger; but to avoid all risk do not bring Dwárka temple inside Kachhigadh fort, or to the southward of S. by E. The south end of Gurur shoal is connected with the shoal water off Chora sand-hills by a shallow neck, having 10 fathoms water, with much deeper water on either side; but as these inequalities in depth are so deceiving, ships had better pass to seaward of the Gurur.

"Between the Gurur shoal and the main, during a calm, on the ebb tide, the sea sometimes breaks even in deep water, and on both tides there are heavy ripplings, causing alarm to a stranger. When standing in towards the Gurur, the change in the colour of the water, the ripplings, and great quantities of sea-weed in large patches drifting on the surface, would sufficiently point it out by day. But the soundings are a sure guide; the 20 fathoms line is decidedly marked, and the water will, when the flood tide accelerates the vessel's speed, generally shoal

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10 fathoms at a cast. During westerly winds there is a hollow breaking swell on the Gurur.

"*By night* a large ship not bound into the Gulf of Cutch, should not shoal under 20 fathoms, off its mouth, as the following bank lies to the N.W. of the Gurur.

"*Lushington Shoal,* called *Ania Mor* by Cutch boatmen, is a shoal patch of sand and rock, the former doubtless brought by the currents from the coasts of Sind and Cutch, and deposited on the rocky nucleus, where the ebb from the Gulf of Cutch conflicts with the S.E. ocean current of the S.W. monsoon. It is supposed to be getting shoaler gradually, $3\frac{1}{2}$ fathoms at low water was the least found in 1850, but there may be a less depth on it. The soundings near it vary from 15 to 16 fathoms at 2 miles to the south, and from 20 to 30 between it and Gurur, from which it is distant 11 miles. A cast of 5 fathoms was found at 4 miles to the S.W. of Lushington Shoal, in which direction a 10-fathom bank extends 16 miles. Shoal patches of 8 fathoms lie to the west of it; from 10 to 11 fathoms is the depth on its N.W. side, whence the water gradually shoals to the Cutch coast. To the east between it and Ranwára shoal, there is a deep gut with from 30 to 35 fathoms.

"*The* $3\frac{1}{2}$ *fathoms patch* of the Lushington shoal is in latitude 22° 37' N., and longitude 68° 48' E. From it Nanáo hill, in Cutch, bears N.E. $\frac{1}{2}$ N., 46 miles, and is visible in clear weather; Beka shoal bears E.S.E. 13 miles, and Dwárka temple S.S.E. 25 miles.

"*The Tides* on Lushington shoal set E. by N. and W. by S. from $1\frac{1}{2}$ to $2\frac{1}{2}$ knots per hour. High water on full and change at 11h. 30m., when the ordinary rise is 10 feet.

Entering the Gulf of Cutch.

"For a steamer or a ship with a fair wind, bound into the Gulf of Cutch, the passage between the Gurur and the mainland of Okhámandal should be used, care being taken that, in giving that shoal a wide berth, the vessel does not go too near the spit off Sainia. The fair channel is 3 miles wide. From Dwárka the tides make strong in and out of the Gulf of Cutch, setting with the line of coast, 2 or 3 knots per hour, increasing to 3 or 4 as Bet is approached.

"Vessels bound to Mándvi from the southward, passing between Gurur and Lushington shoals, should keep Dwárka temple and Kachhigadh fort in one, or bearing S. by E. so long as either can be seen from aloft on that line. Assar tomb, on the Cutch coast, should be steered for, and will bear about N.E. 20 miles distant from outside the Gurur.

Deep Water.

"To the north of the Gurur, between Lushington and Ranwára shoals, there is a gut of small extent, having over 30 fathoms water; from this deep basin (which is a good guide to know a vessel's position) on a fine day Nanáo hill in Cutch may be seen bearing N.E. by N., and all will be clear before you; but due care must be taken to allow for the tides, which set east and west in the mouth of the gulf, about 3 miles per hour. The above bearing of Nanáo hill leads clear in mid-channel between Lushington and Gurur shoal. A steamer may conveniently pass between the Gurur shoal and the coast of Okhámandal, when bound to Mándvi in the day time, and by taking a fresh departure from Sainia island, will not only make more certain of steering straight for Assar tomb on the Cutch coast, but will save several miles.

Bet Inner Harbour.

"On the west side of the fort is unfit for large ships, having so much rocky ground. If wanting to anchor off Bet fort, after the south end of Sainia is brought to bear W.N.W. stand to the S.E., over the flat, for the cocoanut trees, when they are on with a large round tree, until the S.W. bluff of Bet island is just disappearing behind Háji

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Karman's point, when the steamer must be hauled up to the south and west, and may round the latter point at less than 2 cables length, and anchor to the S.W. of it, with Bet fort E.S.E. to E. by S., in 4 or 5 fathoms, rocky bottom. Of course none but a steamer could enter as above, but a small sailing vessel might work in with a N.E. wind.

Directions for entering Bet Harbour.

"There are several channels into Bet at high water; but, for steamers, the passage round the east side of Sainia island is preferred, as the rocky point of its reef shows itself so plainly, and a vessel should pass quite close to it. There is no flood tide felt in this passage, though northward of it across its mouth the flood stream runs 3 or 4 knots to the east and the ebb runs out to N.W. A sandy spit extends for a mile to the N.W. of Sainia island. *Beka shoal*, the N.E. end of Gurur, which has a little sandy knoll, dry only at lowest spring tides, is marked by Sainia tomb just to the left of Bet cocoanut trees. Therefore, when the trees are seen clear to the *left* of Sainia island (seen best from aloft), the ship is well clear to the east of the Gurur shoal, and should stand onwards to S.E., allowing for tide, if bound into Bet, with those marks a little more open till *Chinri sand* bears east, when she may gradually open out the whole of Bet Island to the left or eastward of Sainia island.

"*To enter the passage along the east side of Sainia.*—Having arrived (as above) within a mile to the north of the island, keep a look-out for the N.E. tip of its reef, and steer for it S.S.W., paying great attention to the tide, which rushes past the tip of the rocks with great velocity. Two sandy points of the Okha shore between Sainia and Arámbhada will be seen in line ahead; keeping these in a line will lead a vessel in clear to the east of Sainia reef, which is only partially covered at high water; steer S.S.W. along the east side of the island, not opening out the sandy points till the south end of Sainia bear W.N.W., when a vessel may go a little further south and anchor 2 or 3 cables to the east of the first sandy point, Okha point, in 5 to 7 fathoms, and with Vománi point, which is one mile to S.W. of Sainia island, bearing west.

"With a west wind a ship must wait till half-flood, and then cross Bet Bar, with the east sandy point of Okhámandal on with Bet fort; in this passage she will have more than 4 fathoms towards high water. When in the deep water (with Sainia Pir bearing east), where it breaks even in 10 fathoms when the tide is running to windward, she must borrow towards the south end of that island, and when up to it, haul to the south and anchor to the eastward of Okha sandy point, Vománi mound bearing west, as before."

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DESCRIPTION

OF THE

LESSER RAN OF CUTCH (KACHH).

THE remarkable region called "The Ran of Cutch" may be divided into two portions, the Greater and Lesser Ran. The Greater Ran is that vast tract of perfectly flat country about the level of ordinary high water lying between Cutch on the south and the Thull Desert on the north, and on the east it is bounded by Gujarát Territory. It bends round at its eastern extremity and becomes the Lesser Ran. This Lesser Ran commences between Cutch and "the Chorár," where it is only some 12 miles wide; it extends to the south, spreading out to the east and west until at its southern boundary (*i. e.*, the north of Káthiáwár) it is some 60 miles wide; it again bends at its south-west corner between Shikárpur and Wándhia in Cutch, and Mália in Káthiáwár, where it is only about 5 miles wide, and goes on to the Gulf of Cutch, spreading itself out like a funnel until it reaches the Gulf of Cutch. The present article refers to the Lesser Ran. Opinions are very varied as to the formation of the Ran, and its character; some 10 years ago the question of the secular depression of the Ran gave rise to a series of articles in the newspapers, and the attention of Government was directed to this subject. This resulted in tidal observations being taken with great care by first-class instruments at three points on the Gulf of Cutch, and lines of levelling being executed in connection therewith: these lines passed over some 50 miles of the Lesser Ran at different positions, and thus the actual relation of the mean level of the sea with reference to those portions of the Ran was determined very exactly. A repetition of these operations about 20 years afterwards will settle the question of the secular changes supposed to exist. These operations were conducted by Captain Baird, R.E., under the orders of the Superintendent, Great Trigonometrical Survey. A more detailed account of these operations is given further on.

The limits of the Lesser Ran.

It may be as well to give a more exact description of the limits of the Lesser Ran. On the east it is bounded by the districts of Pátri, Jhinjúváda, and Wáráhi in Gujarát; by the Chorár on the north,—the Chorár simply being a piece of the mainland, formed into a sort of island by being divided from the Gujarát mainland (or coast, if it may be so called) by an exceedingly narrow strip of the Ran. Then on the west the Ran is bounded by those portions of Cutch, called Fatehgadh, Ádesar, and Wándhia; the mainland of Cutch, stretching away to the west towards Anjár, becomes the northern boundary of this part of the Ran. The Hálár Pránt of Káthiáwár is on

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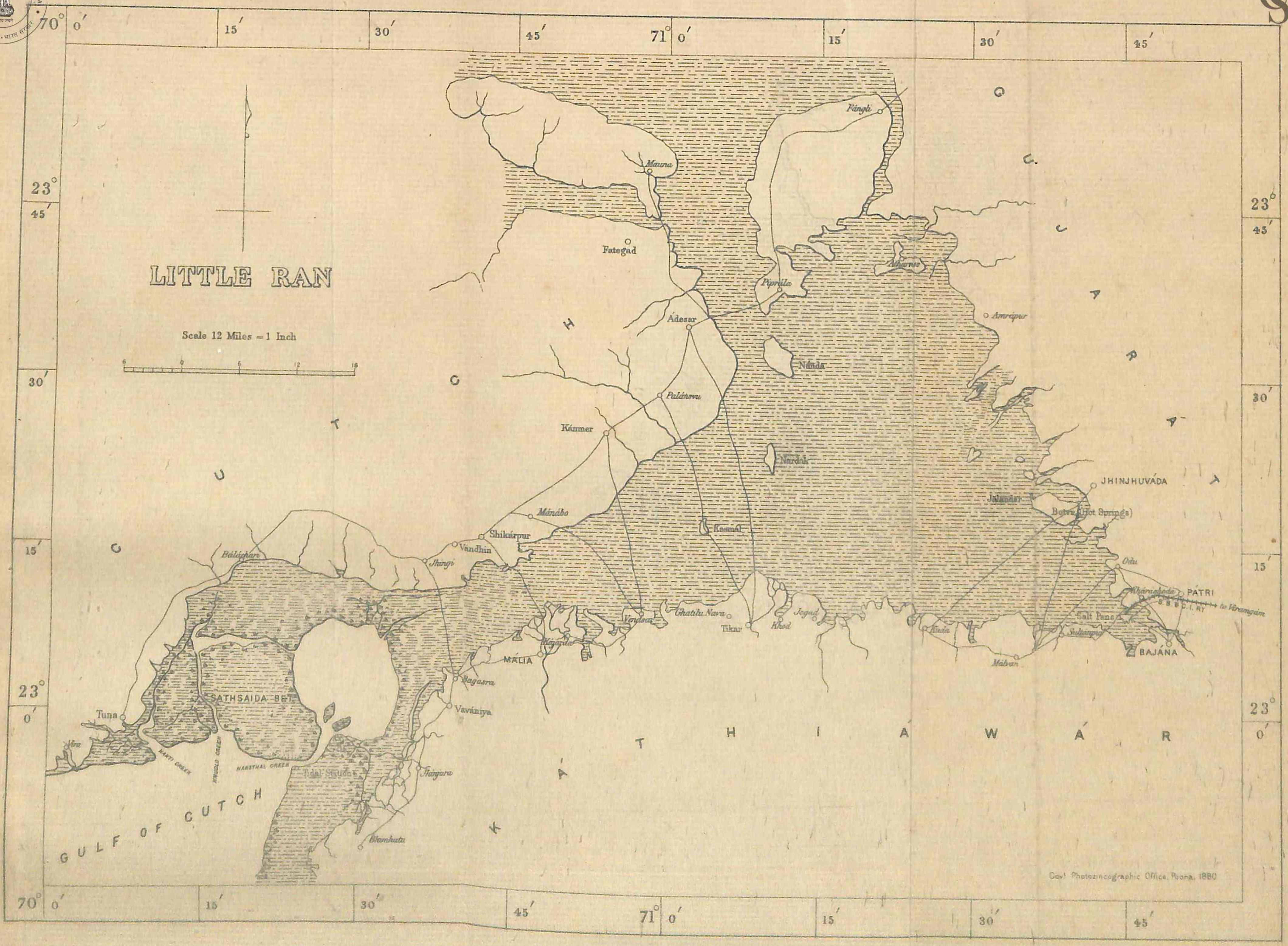

LITTLE RAN

Scale 12 Miles = 1 Inch

Govt. Photozincographic Office, Poona, 1880

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the opposite side of the Ran at this part, while the Dhrángadra State of Káthiáwár forms the southern boundary of the main portion of the Lesser Ran.

Appearance o the Ran.

Captain Trotter, R.E., in describing the Ran, in 1873, with reference to its appearance from the Káthiáwár side, wrote as follows:

"With the exception of a few antiquarian remains, the country is most uninteresting: no mountains or even hills worthy of the name, no fine rivers, or large forests, or picturesque views meet the eye. Towards the north, a partially cultivated treeless plain is all that the traveller sees, with an occasional tank, whose low banks form the only practicable points on which to erect stations for our triangulation. This plain gradually merges into the Ran of Cutch, an extensive desert about which much has been written by various authors, but of which a short description will not be out of place here.

"It is a vast and perfectly flat tract of desert, without a scrap of vegetation of any kind, and so little lower in level than the country to its south, that in many places it is impossible to say where the Ran begins and the mainland ceases. There is often, however, an intermediate strip of land between the cultivation and the desert, on which grows a short stunted grass, the food of the cattle and wild asses, when they can get nothing better. On the other hand, portions of the Ran extend inland in bays meeting the sandy beds of rivers, which all sink and are lost in the sands soon as they come in contact with the Ran.

"In some few places islands rise out of the midst of it, generally showing marks of volcanic action. Some of these islands are more or less covered with grass, to collect which, carts are sent over at the proper season from the mainland. In the cold weather it is possible to traverse the Ran with impunity, as, although the sun is always hot, yet there is generally a cool breeze blowing up from the sea on the west; but, in the hot weather, I have been assured that to spend a day on the Ran would be almost certain death. I have heard of more than one authenticated case where men have got lost on the Ran and have wandered about in a circle until they have fallen exhausted. I can quite imagine this to be true, for, as the hot season advances, the dazzling glare is blinding and the heat overpowering. The mirage distorts and magnifies the smallest objects into the most wonderful shape—a stick appears like a tree, and a stone like a hill, and no distant object can be seen at all.

"The composition of the surface and a subsoil appears to be in tolerably regular layers of sand and clay with a large quantity of saline matter admixed. This saline deposit attracts the moisture from the atmosphere, and the surface is then frequently damp. For some months in the year the Ran is under water. When the prevalent westerly winds begin to blow in March, the water in the Gulf of Cutch is gradually heaped up, and it advances in a slow wave right up the Ran until the fall of the monsoon in June, by which time almost the whole of the western portion is covered with water, varying from a few inches to a few feet in depth. When the rain falls, fresh water is carried into the Ran by the rivers that empty themselves into it, and the whole becomes a vast lake—nowhere more than a few feet in depth, and which subsides gradually at the close of the monsoon. The admixture of the fresh and salt water kills large numbers of fish; and I have, in crossing the Ran, come across the remains of myriads of prawns which appear to have met their death in this manner. I have also in the cold weather seen heaps of dead locusts, which, fortunately for the inhabitants of Káthiáwár, have fallen victims to exhaustion in crossing this desert tract.

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"The Ran is crossed by several cart-tracks. Some of these, towards the head of the Ran, are only closed for a few weeks in the year, and are even then open for horsemen and foot passengers; others, near the head of the Gulf, are closed for half the year, viz., from the first rise of the water in March or April until the subsidence of the waters after the monsoons. At the head of the Ran are the new and extensive Government salt works at Pátri."*

Captain Pullan, writing the following year in his official report, gave the following description of a portion of the Ran:

"The scenery at the head of the Gulf of Cutch is very peculiar: first there is the distinctly marked line of cultivation,—cotton, wheat, 'bájri',—making a pleasant variety of colour and outline; trees are dotted about and villages stand out in relief against the sky, or show white against the green masses of the 'tope' of trees which almost invariably surrounds them. Next comes the dry salt-impregnated surface of the Ran, half sand, half black earth; here and there a stunted bush or two to dot the waste, but, as a rule, it is utterly bare and desolate. A low range of sandy hills shuts in this Ran from the wide-spreading swamps which extend as far as the eye can reach, and are covered with a dense thicket of almost impassable mangroves, and intersected with a close network of salt streams. The sea itself is away beyond the mangrove swamps, and at high tides the waters of the Gulf roll up, covering the morass and washing up the very foot of the sandy hills. A white sail dots the horizon here and there, and the observer is cheated for the time into the idea that he is on the sea-shore; but a few hours after, the illusion is dispelled and the sea might be far away, save for the cool salt breeze that pours through the tents, and brings a reminder of the vicinity of the ocean. While surveying the country bordering on the Gulf, I witnessed some very beautiful effects of 'mirage': at midday more especially, the surface of the soil, glittering with saline particles, seems changed to a glassy sheet of water, the scattered villages assume larger proportions, houses and walls appear gigantic, trees again double height and bulk, while all appears reflected as in the waters of a placid far-stretching lake; but, while the observer gazes in admiration and wonder, the beautiful vision fades, or rather passes on to light up another portion of the coast in like manner. On another occasion the smooth salt surface of the ooze became a still summer sea, such as Van de Velde loved to paint, and on its bosom lay old dismantled boats, white gulls flitted here and there, and far away the grey line of coast closed the picture in the extreme distance. Had I not known that the Gulf was 6 miles off and hardly accessible at all from land, I should have thought myself within a few minutes' walk of the sea, so perfect was the illusion. Nothing grows on these salt morasses, except mangrove and a long coarse grass in scattered patches. Various sea-birds feed at will over the slimy ooze and along the edges of the salt streams that wind their way through the swamp, and in the early morning herds of antelopes may be seen hurrying back to the borders of the cultivation, after having eaten their day's allowance of salt on the edge of the Ran.

"I was agreeably surprised to find that drinkable water is procurable even during the summer all along the borders of the Ran. Here and there the surveyor has to send several miles for good water; but, as a rule, a little care and arrangement is all that is required to enable the traveller to obtain drinkable water all the year round.

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* *N.B.*—These works are called the Khárághoda salt works, and are not new, though they have been greatly enlarged of late years.

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"A very large number of camels are bred along the borders of the Gulf between Jodiya and Mália; droves of them may be seen wandering here and there over the swamps, browsing on the mangrove; inured from their birth to the treacherous slippery ground, they pass along safely over the ooze and swamp, where a Bikánir or Hissar camel would slip and fall before it had gone fifty yards—in fact, where any camel but this peculiar breed would refuse to go at all."

Ran between Mália and Shikárpur.

Captain Baird, R. E., wrote of the portion of the Ran between Mália in Káthiáwár, and Shikárpur in Cutch, regarding his work in levelling over it :

"Between Shikárpur and the Ran the country is almost entirely uncultivated, and there is a series of hillocks composed of fine black sand, which are covered with dense vegetation. These hillocks appear to be moveable; they are dotted here and there over the plain, but the hillocks in the immediate vicinity of the Ran are tolerably high, and form an almost uninterrupted chain for a mile or two to the west, and running nearly parallel to the general line of the Ran.

"On the Káthiáwár side opposite, there are no hillocks, but a tract of waste land for one or two miles, which is cut up by a great number of nalláhs; then we find a mile or two of cultivated fields occupied by the Miánás (who are considered a race of professional thieves). The villages of these Miánás are scattered all over the country here, and there are some 200 of them near the town of Mália. Each village consists of a few straw huts surrounded by the straw hedge, and the flag of the headman of the village is conspicuous in each case on the long bamboo stuck into the ground in front of his hut. These Miánás are considered most troublesome people by the officers of the Political Agency.

"The Ran itself, between Shikárpur on the Cutch side and Mália on the Káthiáwár side, is some 8 miles across; but of this, only 6 miles can be used for the determination of the general level of the Ran, as the ground close to the mainland on each side is from a foot to 18 inches higher. This part of the Ran is perfectly dry from November till the end of March; but about the end of April or beginning of May, it is covered by the water from the extraordinary high tides, and the water is also forced up by very high south-westerly winds which always prevail at that time. The Hansthal Creek, being almost like a funnel at the end of the Gulf, is acted on by the full force of this wind, and the water from the Gulf is thus conveyed far up the Ran.

"The ground over which we levelled was almost quite dry, and has the usual appearance, blackish-grey colour, with here and there patches of glistening white from the salt deposited after evaporation."

Colonel Barton, Political Agent of Cutch, writes of the Region immediately north-west of the Hansthal Creek :

Sathsaida Bet and Inner Gulf of Cutch.

"The inner gulf is a shallow lagoon about ten miles in length from north to south, and eight miles broad from east to west. It is surrounded with swamps, huge expanses of which lie to the west and south, while to the east the swamp gradually disappears in the lesser Ran. These morasses are covered with water at spring tides, and during the prevalence of the south-west monsoon. At other times they are islands raised slightly above the surface of the water and covered with mangrove bushes. A network of tidal creeks called 'nesses' is scattered through the morasses and serves as the arteries through which the tidal water flows from the outer to the inner gulf. The main passage is denominated the Hansthal, which is about five miles long and from half a mile to a mile broad, and is very deep. Taking the inner gulf to represent a nearly circular bottle,

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the Hansthal is the neck which supplies the bottle with water. The tide also flows in by the Nakti and Kundlo creeks, and laterally through a labyrinth of creeks which run at right angles to the Kundlo from Roher on the mainland, in an easterly direction to the inner gulf. These creeks form the northern boundary of an island called the 'Sathsaida Bet,' the western limit being the Nakti, the eastern the inner gulf, and the southern the outer gulf, and the Hansthal passage. The area of this island cannot be less than fifty square miles, and it is utterly desolate. Covered at times by tidal water, its surface is then only distinguishable by the mangrove bushes with which it is dotted. Camels graze there when it is not submerged, and strangely enough, there is a spring of sweet water in the eastern part of the island, which though overflowed by the sea at times still retains its original properties."

Mr. Peyton, of the Trigonometrical Survey, wrote, in 1876, about that portion of the Ran to the west of Pátri and Jhinjúváda, as follows :

"From the mainland on the east, there is a slight but marked descent to the edge of the Ran, the intervening space being covered with short, dry grass, and fragments of sandstone and fine white flint ; but gradually the rock and vegetation give up the contest with the encroaching sand. When I first saw the Ran from the rising ground south of the tank at Jhinjúváda, a sand mist rose on the plain in front, and underneath the surface glistened as if some broad stream were sleeping in the sunbeams. In the cold season the Ran is partly covered with surface water, often nearly dry by the end of February, and partly either by firm and rather moist sand and mud, or by a crisp white coating of crystallized salt. As the hot weather sets in, a scorched naked plain is all that is left, and upon it the sun beats down with an intensity of which no one, who has not travelled there in April and May, can form any idea. Then, as the rains begin, or as the tidal waters advance up the channel of the gulf of Cutch, the Ran is submerged and looks like an extensive inland sea. In olden times the ocean here beat upon a gently sloping shore, forming bays and occupying much of the level tract of the east, now covered with cotton cultivation. At a later period, a narrower limit circumscribed the waters till the last remnant of the sea was but a long strip of an average breadth of 40 and 50 miles, enclosed by the coast-lines of Cutch and Káthiáwár. At the final elevation of this tract, the waters receded to the main ocean through the Gulf of Cutch, leaving a briny sediment to encrust the new plains and impregnate the drainage of the adjacent districts. The traveller from Jhinjúváda approaching the Ran might well imagine that the sea had only ebbed for a few hours from the sandbanks in front. The withdrawal of the ocean is inscribed on every mound he passes.

"The Ran presents a variety of surface. In several places it has a thick coating of salt, crystallized by the action of the sun. This encrustation is sometimes more than a foot thick. The banks of the Rupen present a singularly white appearance, and the illusion of a half-frozen river covered with a heavy fall of snow would be complete, but for the intense heat of the sun overhead. Where only a film of salt lies on the surface, the Ran is of a cream-white colour. Where clay predominates, it is honeycombed with cracks. Then again in several places the mud is contracted into saucer-like forms, the edges being somewhat sharp, showing that after the water that collected in the rains, had dried up, leaving the edges soft, the heat had eventually baked and caused the mud to contract and curl up in the above-named form. Here and there the mud is disposed in layers, which crack off in places from each other like the sheets of an unbound book. It will thus be seen that

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a traveller in the Ran comes across a variety of ground. At one time he laboriously picks his way over a surface broken by fissures; at another, he sinks deep in mud, or finds himself on a hard bed of very firm clay, on which the foot scarcely makes any impression. On one day he plunges for miles knee-deep in soft mud and loose sand-drifts; the next day he is on a hard pebbly surface, which permits a canter for hours over the level plain, amidst dwarfed, leafless, and dust-coloured shrubs. A feature of the Ran which must not be unnoticed is the phenomenon of the mirage. The most beautiful mirages are seen here. They most minutely resemble seas and lakes, in which trees, hills, barren grey rocks, and everything in their vicinity are reflected as if in the clearest water. They form a remarkable contrast with the staring dry desert, and have probably deceived many a poor wanderer. If one be not aware that no water is there, it is quite impossible to distinguish the appearance from the reality. The common kind of mirage is that which exhibits a sheet of calm, blue water, presenting it as close at hand, and then withdrawing afar off, always deluding the eye with imaginary and ever-changing distances. Very often in the middle of the day, when the sun attains its full force, the distant plains seem converted into a sea of glass. It is curious to notice the appearance of Jhilánand with its grass-covered margin, and here and there bright bits of sparkling water. There is the sea of glass, no doubt; but the land, covered as it is sure to be with vegetation, from the thin line of golden sand at its base, to its summit, looks like an extensive oasis, not only standing out of water, but suspended in the air. Land and water do not meet; you can see a broad band of space separating the one from the other. You can see under the land. You can see also that this is not got by blotting out the lower portion of the island, for you can distinctly recognize, though completely separated from the water, the sandy beach and the lowest objects which the land contains. On the mainland I have frequently seen the villages, which were, in reality, flush with the ground, as if they were perched on semi-transparent rocks, their edges rounded off, and fading into a golden haze. On one occasion a most perfect picture of trees, surrounding a long narrow lake, beguiled me some miles out of my course, and then disappeared in the wild expanse of sand. Most objects in the Ran appear on an enlarged scale. From a distance the wild asses look uncommonly like a lot of camels tramping through the snow, their shadows reflected vertically under them. Skeletons and bones of cattle, which are often met with on the borders of the Ran, seem at first sight like rows of crystal stones scattered in groups through the plains. On one occasion I saw a black buck under such circumstances that it required little stretch of the imagination to mistake him for an enormous rock that had been overturned and swept into the Ran by a heavy sea. He was standing with his back towards us, as motionless as a target, on a plain that extended as far as the eye could reach, and it was not till I approached within 50 yards that what appeared a big rock, or a huge spectre, turned out to be a deer.

"At the close of February I made an excursion to the island of Wáchra Solanik, a bare, brown, desolate-looking place, with a low arid shore rising gently from the Ran. Owing to the large mass of water which at this season covers the Ran between the islands and the mainland, there is no direct communication with Wáchra Solanki from the Jhinjúváda coast before April. But the island is accessible from the village of Khorda, north-west of Jhinjúváda, lying as it does on the further side of two rivers which supply this water, and which by taking this route is crossed where it is shallow and within a narrow channel before it expands on the muddy plains of the Ran. Proceeding south-

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west from this village, and passing the cotton-fields (which are not here fenced by cactus hedges) that edge the road, you reach an open space with sand-drifts over it, and dotted with prickly shrubs. As you approach the Ran, you see in front a barren sheet of glaring sand, with a fringe of withered bush and stunted trees upon its borders, which cuts the yellow expanse of desert. The island juts out from the sun-dried plain, and seen through the molten air quivering on the overheated surface, has a strange weird appearance. It is a weary trudge into this island from the village of Khorda. For seven miles by the dead level of orange-coloured sand, over ground dotted by small and colourless desert shrubs, through salt wastes without a scrap of earth or a vestige of the minutest vegetation, on to a narrow strip of sandy soil, sometimes widening into a small plain, and bounded by masses of naked rock. This is Wáchra Solanki. There is here neither stream nor well ; but there are one or two springs, the water of which is said to possess wonderful medicinal properties, hydrophobia being one of the diseases for which it is believed to be an infallible remedy ; but so far as I know, judging from a spring near the spot where my tent was pitched, the chalybeate taste of the water renders it unfit for drinking. It is perhaps solely to the supply of water from these springs that this oasis owes its existence. Yet it contains no fresh water, and is hardly adapted for human habitation. Thousands of pilgrims from great distances visit the springs in the hot season, and all the sacred interest of the district centres in their neighbourhood. There was a prevalent notion not long ago that this portion of the Ran was dangerous for travellers—a haunt of brigands and unscrupulous murderers. It is impossible to remember or record, as it was impossible even on the spot to verify, half the stories I heard of murderous attacks on travellers by bands of freebooters and brigands. Here is a sample : Just six years ago, a rich Bráhman, with laden camels and two followers, was coming up from Dhrángadra. As they neared the outer edge of the belt of scrub which extends between the Ran and the high ground in the centre of the island, two men, clad like police sowárs, and mounted on fine horses, rode up to them, and one fellow, pointing a gun at the head of the first traveller he met, put before him the alternative of his money or his life. A scuffle ensued. The first two were killed on the spot ; the third was knocked off his horse, and after the thieves had tried to suffocate him by cramming mud and sand into his mouth and nostrils, they left him alone and proceeded to rifle the contents of two trunks containing jewelry and large sums of money. The camels and horses strayed away, but the wounded man, with limbs literally riddled with shot, started in the dead of the night, and after pursuing his way without sleep for 24 hours through the wilderness, reached the village of Khorda. Sowárs were sent to Wáchra Solanki to look into the matter : they saw traces of camp fire and the marks of a scuffle,—nothing more. But since this occurrence a permanent guard has been stationed here, and to a great extent the roving bands of robbers, for which the spot was notorious, have been broken up. But solitary places like this, far out in the Ran, offer great facilities to such men for concealment, and, armed as they are, and well mounted, they are ugly customers when they venture to show fight. The Rádhanpur authorities have built a large house on the eastern edge of the island, and around it are a few huts made of framework of wood, filled in with branches of trees, and thatched. They are occupied by seven or eight sowárs and a few policemen from the Salt Department.

"The Ran near Wáchra Solanki is inundated in the early part of the cold season by the Rupen and Sarasvati rivers. The Rupen traverses the cotton plains north of Jhinjúváda, and has a general course from east

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to west till it enters the Ran, when it forms a crescent, and taking a south-westerly direction, joins the Sarasvati, a little to the west of Wáchra Solanki,—the water increasing very considerably in breadth at their junction, while one arm branches off round the southern part of the island, and, seen from its rocky coast, seems to extend as far as eye can reach. Even in the month of March, the water here gives to the Ran a singularly sea-like appearance. It decreases as the hot weather sets in, and nothing of it is left in the month of May. But there is a tradition among the villagers of the opposite coast that formerly this part of the Ran contained a permanent supply of water, and that it was habitually navigated by boats. If this be correct, of even the most remote epoch of historic memory, the steady elevation of the surface of the Ran must have continued long after the cultivated district, with which it is bordered, assumed its present character. In several places before the Rupen reaches the Ran, its water is lost in the sands, but reappears here and there, while in the Ran itself it keeps entirely to the surface, till it is finally lost in the plains south-west of Wáchra Solanki. Much of the water is drifted about by currents of wind, and has therefore no fixed limits ; at one time here and at another there ; and it is simply surface water, without any defined banks ; when the Ran is dry, it would be impossible to point out any particular portion occupied by it in the cold season.

"From Dassára the road to Jhinjúváda is across a flat open country covered with cotton cultivation. You first pass a clump of *nim* trees and the *thána* at the north end of the village, and crossing a sandy heath, you get amongst cotton-fields, which generally—shut off by dusty hedges of cactus, broken here and there by foot-paths—eventually line both sides of the road. In several places the cactus leaves the road, but the cotton-fields are continuous till you are within two miles of Jhinjúváda, when they are intermixed with grain crops. The entire journey is through an extensive fertile tract, with open fields, tanks, and villages interspersed in all directions. West of Jhinjúváda the cultivation, in small isolated patches, makes its last struggle against the Ran. Here and there are sandy hillocks, or beehived-shaped mounds about 3 to 5 feet high, covered with small scrub of a sort of dwarf tamarisk and other withered shrubs ; but all beyond is the Ran, with the level, featureless surface, and the even horizon-line that meets the sky, although near the Ran, Jhinjúváda is well sheltered by trees, conspicuous amongst them being two palms, which seem to have grown together, and are exactly of the same height. The village is on the site of an old town, which was enclosed by a quadrangular fort, much of which has crumbled away."

Ran between Jodiya and Hansthal.

This portion of the Ran had to be traversed frequently by Captain Baird and his assistant while going to Hansthal station, and of his journey, in May 1873, he writes :

"Our only landmarks were, in the whole of the last 14 miles, two small mounds of earth thrown up when there were postal chaukies there at 4 or 5 miles apart, and the observatory itself ; we both felt a curious sensation, as if we were being carried out to sea, which was occasioned by seeing small branches of scrub floating on the surface of the water, and being driven by the wind inland, and once, with the exception of one of the mounds above-mentioned in the distance, there were no fixed objects visible to destroy this optical illusion."

The attention of the Government of Bombay was, in 1867, directed by an article in the *Bombay Saturday Review* to two very important questions, namely, the filling up of the eastern shores of the Gulf of Cambay and the supposed depression of the Ran of Cutch.

The question was referred to Professor Oldham, Director of the Geological Survey of India, for his opinion and advice, and his memorandum was published, together with a resolution, determining to have proper soundings made, and also suitable benchmarks fixed in order to determine the question of the depression of the Ran. The relative elevation of these permanent benchmarks was to be ascertained with reference to the 'mean sea-level,' and in order to fix the 'mean sea-level,' a series of observations were to be made extending over several lunations.

In his memorandum, Dr. Oldham wrote:

"I must give a caution against admitting as conclusive evidence in favour of a general depression of the Ran, the single fact that the lands of the village Bhimkata had been washed away. Such a case may very probably be due to local causes, and is not, taken alone, any proof of even a general encroachment of the sea, much less of a general depression of the land. I am by no means aware, either, that it is 'universally admitted' that the Ran is an upheaved sea-bottom, upheaved by volcanic action! Grant, who gave an admirable description of Cutch in 1837, did not think so, as he describes it as being filled by deposits brought by rivers. And Mr. Blanford, writing long before this article was submitted to him, described it 'as the bed of an inlet of the sea filled up by the accumulation of detritus brought down by the rivers. It is just at present in the debateable state,—water part of the year, land another part; but every year must increase the height of the land surface, and consequently diminish the depth of the water at the period of the overflow. Of course the whole may be an area of depression, but further proofs of this are necessary than the fact of a small portion having been sunk (and another raised) by the earthquake of 1819.'

"To determine the facts as to whether a gradual secular depression is taking place in the Ran or not, will need careful observations. The annual flooding of the Ran is stated to be caused by the sea being forced up the Gulf of Cutch and the more easterly mouths of the Indus by the south-west monsoon, the waters poured into the Ran by rivers being thus ponded back. If this be the case, it will certainly result that the depth to which the Ran is flooded during different years will vary with the intensity of the monsoon, and with the amount of the waters brought down by rivers. Observations, therefore, at that time of year would be worthless if used to determine any changes of level. To obtain any trustworthy results, I think it will be essential to erect fixed and solid marks—pillars of masonry, with solid foundations—at intervals along the coast, and in the neighbourhood of tidal creeks *as far within the Ran* as practicable, and an accurate determination of the height of a point upon each above *mean tide-level*. A very few of these would suffice if placed at well-selected points.

"I have spoken of the necessity of an *accurate* determination of the level of these points. It is an easy matter to determine with accuracy the difference of level of two fixed points not far distant from each other. But in the present case it is necessary in the first place to fix one of those points before the relative level of the other can be ascertained. The exact line of mean sea-level must be determined. This can only be done by a series of observations steadily and systematically pursued daily for more than a month at intervals, or for a year, if practicable. There is no real difficulty in the case; it only requires ordinary care, but this care continued for such a time as to eliminate the disturbing effects of local or temporary causes. Once determined, these observations need not be repeated again

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for several years, say ten, when the exact relative level of the fixed mark as compared with the mean tide-level should be again determined.

"It will be sufficient, to prove the necessity for great care and accuracy, to state that in every case in which such a secular change of level has been established, the change has not amounted to more than a few inches, or a foot or two in a hundred years."

The question of the secular depression of the Ran was viewed in very different ways by some of the Political Officers in Káthiáwár, who had made the subject one of local enquiry. Captain Hebbert, Political Assistant, writing in April 1867, says:

"Much has been written on the general subject of the oscillations in the level of the Ran, by Captain Grant, of the Engineers, Fulljames, Le Grand Jacob, and John Jacob, and many papers referring to it will be found in the transactions of the 'Bombay Geographical Society,' and in the 'Journal of the Royal Asiatic Society, Bengal,' chiefly from 1830 to 1840, and in Burn's Travels, Dr. Burn's Mission to Sind, and Lyell's 'Principles of Geology.'

"The Ran, as often before described, is an extensive sandy flat, with well defined boundaries, lying on a lower level than the surrounding country, and very little above the level of the sea. It is devoid of vegetation, except on the elevated ridges alluded to in Captain McMurdo's Report on the Province of Káthiáwár, dated 2nd October 1815.

"This tract of country is annually covered by the sea, which is simply blown up upon it by the force of the south-west wind.

"In March the sea commences to flood the Ran on the Cutch side to an extent of about 2 miles, and to a depth of from 2 to 2½ feet. In April the Ran is covered as far as Tikar to a depth of 1, 2, and, in some places, 4 feet; and during the violence of the monsoon, when the Soonee, Banás and other countless streams pour in their floods, the depth increases in some parts to 10 to 12 feet, a vast lake being formed, extending far away inland, and not unfrequently, when the rivers are much swollen, connecting itself with the Null to the south, converting Káthiáwár for the time being into an island.

"Captain Grant, in writing of the Ran in his very able papers on the Geology of Cutch, dated 31st December 1836, describes it as 'perhaps unparalleled in any known part of the globe, as it may be said to be placed on a level between land and water;' and certainly it appears to me that the chief peculiarity of the Ran is that it thus retains its level year by year, considering the sea of waters that so continually sweep over it, entering and flowing off, as we can easily conceive, with no insignificant force.

"As far as my observations have enabled me to determine, I am decidedly of opinion that no perceptible change has occurred in the actual level of the Ran for many years, and that the supposed subsidence which has attracted the notice of the writer in the *Bombay Saturday Review* is merely the result of changes which have occurred, and which must occur at the entrance of the Ran, from the annual scour to which it is exposed.

"From interrogating the inhabitants, I am satisfied that no depression, at least on the southern side of the Ran, has been observed by them.

"It appears to me that, were a gradual depression taking place over the entire Ran, caused by volcanic action, we might expect to find evidence of such in changes in the interior of the Ran; and large lakes would remain after the subsidence of the flood, which would increase in extent from year to year.

"Many such lakes have from time immemorial existed in the Ran; but, in spite of the strictest inquiry, I have heard of no instance of these lakes being materially increased, or of fresh ones having been formed: on the contrary, some of them have, if anything, become diminished.

"I directed minute inquiries to be made with a view of ascertaining whether the level of water in the village wells near the coast is approaching nearer the surface or not, as this appeared to be a practical mode of ascertaining whether the neighbourhood of the Ran is undergoing depression; and the result of these inquiries satisfied me that such is not the case.

"Failing, therefore, to discover any foundation for the statement that the Ran was undergoing a yearly depression, I directed my attention to the Gulf of Cutch and entrance to the Ran; and here it was apparent that many of the creeks and channels had undergone considerable changes.

"The whole coast of Káthiáwár in the Gulf of Cutch, north of Navánagar, is formed by thick banks of mud and marsh and mangrove swamps, washed up and accumulated from the, at all times, muddy waters of the gulf; over these marshes the tide is continually ebbing and flowing, and they are subject to the changes noticed before as occurring in the Ran from the sea being forced up by the south-west wind.

"It is not, therefore, to be wondered at that the inhabitants who live near the coast have observed no particular changes, and, when questioned, merely state that some years the sea advances further in the swamp than in others. The only information I found to be obtainable was from boatmen who frequent the navigable creeks.

"The first of these creeks is the one mentioned by the writer in the *Bombay Saturday Review*,—Vavnya Creek, in which native vessels of considerable tonnage can pass more than a mile beyond the former anchorage.

"The next, a few miles to the south-west, is the Jhinjura, a part of Navánagar, in which it is reported that boats can approach 1½ miles further than they were able to do 20 years ago. The Bandar in this creek was formerly at a spot called the Sooee Walo Ness, whereas now it is some distance up the creek. In this, however, one fact is worthy of notice, *viz.*, that although a sufficient depth of water for vessels to pass extends further inland, the depth at the Sooee Walo Ness has scarcely increased at all.

"Again, still further to the south, between Bálamba and Jodiya, the river Dadhiáli flows into the gulf, and it has been noticed that this river has of comparatively late years swept away great quantities of sand and deposit from its mouth, which is by this means considerably widened. Consequently, in the hot months, when there is an increase of water in the gulf, the sea, entering the channels thus formed, spreads over the low sandy level around to a much greater extent than in former years.

"The result, therefore, of my inquiries along the coast has only brought to notice that the degrading action of the Vavnya streams and the Demee, Fooljur, and Dadhiáli rivers have immaterially increased the length and depth of the muddy creeks into which they pour themselves.

"There are certainly some popular traditions, such as that, in past ages, there was a footpath from Jodiya to the opposite bandar of Tuna in Cutch; also, a report that some stones which rise up four miles to sea in front of Báláchadi (the usual resort of Europeans in the hot weather) are the remains of a temple to Shiva;—but for my own part I do not place credence in these reports, which are unsupported by evidence of any kind.

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"The writer of the article submitted for report, unhesitatingly declares his belief that the Ran is undergoing a gradual depression, and affirms that this is undoubtedly caused by volcanic action, and not by the eroding action of the tide.

"That the Ran has been subject to occasional volcanic action is assuredly the case, but that it is now being gradually sunk by this action is very questionable. If a cause such as this were affecting a large tract of country with an area of upwards of 7000 miles, it would not be unnatural to look for repeated and constant indications of a volcanic nature; but this is far from being the case, and from enquiry I am convinced that earthquakes are as little frequent on the Ran as in any part of India. It must, however, be remembered that I have only had opportunity of questioning the inhabitants of the Káthiáwár side of the Ran. The igneous nature of Cutch, on the opposite side, is well known, and earthquakes may be more frequent there: still, I consider that the very fact of earthquakes being almost unknown on this side of the Ran, even if they should be felt on the opposite coast, goes far to prove that the Ran itself is not the centre of their action.

"The only earthquake of importance which has been noticed in the Ran occurred in the year A.D. 1819, and was described by Captain Grant. This earthquake is reported to have rent the deep chasm in the Ran, now known as the Chás, opposite Jhingi, which terminates the Gulf of Cutch, or rather connects it on the Cutch side with the Ran. This channel is constantly being enlarged by portions from the sides falling in and being carried away by the tide, and vessels safely proceed where, previous to 1819, they were unable to find a road.

"It has hitherto been the common impression that the Ran was rising, rather than lowering, in level; and this impression was shared by Captain Grant, and unquestionably this is what we should expect from the operations of the volcanic agency believed in by the writer in the *Bombay Saturday Review*, such agency being calculated to elevate rather than depress. But the gradual rise of land is so slow a process that it would be a most difficult matter to ascertain.

"It requires more than the mere fact of some alluviæ here and there being recaptured by the sea, to prove that the Ran is undergoing a gradual depression. It is a question of levelling, and the only way that suggests itself to me, should Government desire further and more accurate information on the subject, is that a qualified officer be appointed for a few months to superintend the placing of some long lines of levels, which should be run out from some fixed elevation on the mainland of the Ran. Permanent bench-marks should be fixed at regulated intervals, and any changes of level by these means ascertained at stated periods.

"After all, if it should be the case that volcanic action is inducing subsidence now, who can promise that the same action will not re-elevate the Ran and its neighbourhood at a future time."

Captain Watson, Political Assistant, also writes about the same time:

"When I visited the Ran in 1865-66, I observed that, although there can be little doubt that the extent of water in the Ran was formerly at some remote period of time very much greater than it now is, yet that this water appears to have gradually receded owing to oscillations in the level of the Ran, and it seems to have reached its lowest point about the middle of the last century. At all events, since that time the Ran appears to have again commenced to sink, and the sea-water consequently to pene-

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trate further and further eastward, and to cover a large extent of the Ran during the hot seasons and the rains (*vide* McMurdo's Report to Government, dated 2nd October 1815). Since then the level of the Ran has continued to be gradually depressed, and the sea-water each year covers a large extent of territory. In proof of this, when I was at Bálamba in the end of 1865, the villagers told me that formerly, even within the memory of man, there was a footpath across the Ran from Bálamba to Tuna in Cutch, but that the gradual advance of the sea had closed this pass. Close to Bálamba is the village of Bhimkata, under Amreli. The frontier of this village was defined by Colonel Rigby a few years ago. Since that time several acres belonging to Bhimkata had been overflowed by salt-water and become Ran. The whole of the inhabitants of the southern shore of the Ran state that the sea is advancing rapidly. I believe the southern shore to be the very best place for investigations to be made as to whether the level of the Ran is being raised or depressed. Ten years' observations here would set the question at rest.

"My opinion is that at some remote period of time the level of Káthiáwár was depressed considerably lower than it now is; and the present appearance of the Ran and the Bhál confirm my supposition. Any unprejudiced observer examining the Ran and the Bhál or low flat salt land between the Null and the Gulf of Cambay, must perceive that the sea has but comparatively recently withdrawn from it, and that formerly Káthiáwár was an island. I consider that a period of upheaval followed the period of depression, and that now another period of depression has commenced. At the present day, in a heavy rainy season, a light canoe might be paddled from the Ran of Cutch to the Gulf of Cambay, or nearly so. My reasons for supposing that a period of upheaval followed that of depression are, that while we see that the sea is yearly encroaching both in the Ran and on the southern coast of Káthiáwár, we yet see that the extent of Ran and Bhál that must have at one time been covered by salt-water is very considerable, and probably at least three centuries will be required at the present rate of depression to restore the Ran to its pristine condition of an inlet of the sea. The earthquake at the commencement of this century, which formed the Lake Sindree, had doubtless an important effect on the Ran, and the slight shocks experienced in late years have no doubt been tending to the same object, *viz.*, a general depression of level."

Of the drainage, into the Ran, of the Jhálávád Pránt of Káthiáwár, Major Watson says:

"The drainage of the whole country of Jhálávád flows into either the Lesser Ran of Cutch, or the Nal; but the streams of the Dhrángadra territory flow without exception into the Ran. This Ran is drained by two depressions in its surface, the northern of which is called the Wagad Sarnu and the southern the Jhálávád Sarnu. These depressions unite further to the westward, and after their junction are known as the Siri Sarnu. The Jhálávád Sarnu is connected with the Hansthal Creek. Two branches of this creek have been slowly eating their way eastward for the last sixty or seventy years, but during the same period the eastern portion of the Ran has been gradually silting up, owing to the yearly deposit of silt by the Banás and other streams. So marked is this silting up, that, whereas in A.D. 1813, Captain McMurdo, after an elaborate investigation, reports that the Tikar Pass is open to carriages from 15th January to 15th April, it is now open from about December 10th to May 10th—that is to say, for five months instead of three. Further, Captain McMurdo, in his interesting report above alluded to, speaks of the sea-water being detained opposite Koparni until it has 'surmounted a low ridge of sand and drift which is collected like a bar and runs across from about Koparni : this bar is scarcely perceptible. When the water rises above this, it flows without obstruction to Pátri, which is 14 miles east of Dehgaum.' Now (1878) the salt-water never reaches Koparni, but ceases to advance beyond a point which may roughly be said to be opposite Jogad, at least 8 miles west of Koparni.

"The islands in the Ran belonging to Dhrángadra are: (1) a portion of the Kesmal Island, which is shared by Dhrángadra and Cutch; (2) the two Bhangoria islands, which belong entirely to Dhrángadra; (3) the two Ratria islands, which belong entirely to Dhrángadra; (4) Sahiblana, which belongs to Dhrángadra alone; (5) Wala Dungari and Jarakh Dungari, which belong to Dhrángadra alone; and (6) the Mardak Hill, which also is the sole property of this State."

In the Great Trigonometrical Survey Report for 1872-73, the following description of the salt manufacture in the Ran is given:

"For more than a hundred years past, salt has been manufactured from water taken from wells dug in the Ran, more particularly at Kura in the Dhrángadra State and in Pátri, and the neighbouring villages of Khárághoda, Bajána, and Uru, on the eastern border of the Ran. Government has hitherto contented itself with levying a very heavy duty on all salt sold in our own districts; but on account of the large amounts smuggled from Káthiáwár, and also from the above-mentioned places, Government has been compelled to undertake the manufacture itself. With this end in view, all the old Ran works have been closed (with the exception of those belonging to Dhrángadra—an independent State in Káthiáwár), compensation having been paid for old interests involved. All the works also on the western coast of India, between Cambay and Bombay, are to be, or have been closed; and all that part of the country will be supplied with Ran salt manufactured at the Government works. It is hoped, by these means and by an introduction of an efficient line of patrols on the frontier, between the Káthiáwár States and our own districts, it may be possible both to keep the Kura salt from getting across to our own and the Gáikwár's territories, and at the same time to prevent the Málwa opium from getting to Káthiáwár.

"Prior to Government taking over charge of the new works at Pátri, the salt was manufactured by the 'ágariás' (as the makers are termed) on their own account, in quantities limited by Government, to be sold to private merchants at a maximum rate of 2 annas per maund. Practically, they did not get this price for it, as the merchants who purchased generally did so (on account of the abundance of the supply) at a much lower figure. Government now employ these same 'ágariás,' let them dig the wells and make the pans (giving them advances for that purpose), and purchase the whole of their stock of salt (if of approved quality) at 1¼ annas per maund all round, removing the salt to warehouses on the adjacent shores, that have been constructed for the purpose. The ágariás are therefore really much better off than they were before; as formerly that portion of their stock which remained unsold before the periodical setting in of the monsoon (when the whole of the works are flooded and the wells and the pans filled up) was liable to be swept away. This actually occurred the year before last, to the utter ruin of the salt-owners, and I am informed that 42 per cent of the entire produce of the last five years has been washed away in the same manner.

"It was proposed to manufacture during the past season twelve and a half lakhs of maunds of salt, which is a little above the amount estimated

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as required for consumption in that portion of the presidency lying between Bombay and Ahmedabad. For this purpose, 252 pans, each 250 feet long by 60 feet wide, have been constructed. The process of making the salt is very simple, and is almost the same at Pátri as at Kura; but at the latter place the pans are arranged in no sort of order, being scattered in all directions all over the place, whereas at Pátri they are arranged symmetrically in rows, with spaces between for storing the salt. As soon as the monsoon has come to an end and the piled-up waters of the Ran have retired, each 'ágrio' sets to work to dig a well and to make his pan. The well has first to be sunk, as, without the water procured from it, the workman would be unable to puddle and render water-tight his pan. The sinking of the well, which he accomplishes with the aid of hired labour, occupies him some weeks. He soon reaches water, it is true, but only what is termed 'surface water,' and which does not contain nearly so much salt in solution as another kind of water which he reaches generally at a depth of from 20 to 30 feet, on reaching which there is generally a rush of very strong brine, which comes up with considerable force and rises several feet in the well: when he gets this rush of water, he is satisfied, and commences to prepare his pan. Sometimes, however, instead of tapping the brine, he comes to hard red clayey soil called 'morod,' and the experience of the past years has shown that when he comes to this he must abandon all hope of getting to the brine, and start a fresh well elsewhere. Assuming, however, that he has reached good water, he prepares his pan by raising a small bank of earth all round it. He then pumps up water with the common balance-pole and bucket, and covers his pan with it to a depth of one or two inches. This water sinks into the ground, and he then commences to puddle the pan by constantly (with the aid of his hired assistants) treading the ground—a most laborious process, for the pouring on of water and treading and consolidating has to go on until the bottom of the pan becomes quite waterproof, which from the quantity of clay in the soil, it ultimately does, of course in some soils quicker than in others.

"This preliminary of well-sinking and pan-preparing generally occupies about two months. When ready, the brine is pumped in to a depth of several inches, and left to evaporate. As soon as the greater portion of the water has done so, more water is poured on, and this is repeated perhaps once in three or four days. Crystals of salt soon form at the bottom, and the ágariás have to stir these crystals about frequently and briskly with a large rake. This goes on until a crop is ready, which generally happens about the middle of February, when, all the water being allowed to evaporate, the salt, which then forms a layer several inches in depth over the whole pan, is taken out and arranged in conical heaps by the side of the pan, whence, under the new arrangements, instead of being left on the ground and sold as the opportunity offered, it will immediately be carried on a tramway by trucks to the central stores, about 2½ miles off and on high ground bordering the Ran. There it will be weighed and handed over to the Government official deputed to receive it. This central store has been connected by a branch railway line, about 22 miles in length (Pátri to Viramgám), which has been specially made for the purpose, and which was in course of construction while we were surveying the ground. The salt will be carried by the Railway Company to the depôts that are to be formed at Ahmedabad, Broach, Baroda, Bulsár, and Surat, where it will be stored away and sold to the public at a fixed rate.

"Instead of taking one crop in February and another in April or May, a supply of better salt is obtained by continuing the manufacture without emptying the pan until April or May. An average crop of 18 lbs. per superficial foot of evaporating surface may be obtained from a good crop up to the middle of February, and for the second crop a somewhat larger quantity; if the crop be taken at the end of the season, only about 34 lbs. of salt of a superior quality may be obtained per foot. These quantities depend very much upon the amount of brine that may be pumped up, and if a man is lazy, he will get a small return. The brine also is variable in quality, and some wells will give more salt than others. In March and April the salt is apt to receive very serious injury from the clouds of dust and sand that fly about. The Dhrángadra works at Kura appear to suffer more from this cause than the more protected works at Pátri. At the former place, I was told that the manufacture was generally entirely stopped, from this cause and from the supply of water in the works running short, about the end of March or beginning of April.

"The heat in the Ran being so excessive, it has been arranged that all labour of carriage and storage at the Government works shall in the hot weather be carried on at night. At Kura the salt is generally made from surface water, as they cannot obtain the brine springs which afford so rich a crop at Pátri. The reason is, I believe, that the whole ground at Kura is underlaid with 'morod,' and thus, the water being deficient in quality as well as in quantity, they require two wells instead of one for each large pan: the process of manufacture is the same.

"I estimated, after careful inquiries and measurements, the sale of salt at Dhrángadra to be about one lakh of maunds per annum. It has, however, been estimated by the Customs Collector of Bombay at as high a figure as four lakhs, of which he assumes that three lakhs are smuggled across our frontier, causing a loss to our income of nearly six lakhs of rupees. Although we have been in correspondence on the subject, we cannot arrive at less discordant results. The calculations are somewhat elaborate, and I need not give them here; but my own figures are confirmed by the statements of the Darbár officials, who, however, would naturally be disposed to estimate it at as low a figure as possible; for everything over one lakh, which has been assumed to be the probable consumption in Káthiáwár itself of Kura salt, must be admitted to be smuggled.

"In the Kura works, the digging of the wells and making of the pans are undertaken by and at the expense of the ágariás, who are assisted by their families, and follow no other avocation. At our own works the salt manufacturers are also cultivators. The produce is generally sold at about 12 annas the donkey load (2½ maunds), but varies from 10 to 13 annas. According to quantity of the total amount sold, one anna in the rupee is taken when the accounts are made up (annually) to defray the expense of establishment, which is very small, consisting of one kárkun, one havildár, and five peons: the balance is divided between the Darbár and the ágariás. Each, therefore, receives say 5½ annas per donkey load, or 2⅕ annas per maund clear profit to the Darbár, and profits, less working expenses, to the "ágariás". Besides this, there is a small duty levied, of 2 pies per donkey load, or Rs. 1-8 per cart load.

"The pans vary in size from 2500 square feet to 10,000 square feet, as against a uniform size of 15,000 square feet at the Pátri works. There are 80 wells at work, but in most cases two wells are required for each pan. I purchased salt, retail, in the village of Kura at 112 pounds the rupee.

"I have heard it suggested that the brine at Kura wells was supplied direct from the sea, by subterranean filtration. I made some experiments

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in the cold weather to test the same, but could detect no positive traces of tidal influence. It is true there were periodically diurnal rises and falls in the waters of the wells; but this I clearly traced to the effect of the pumping of the water up from other wells, and the consequent lowering of the level of the water in the adjacent wells. I had proposed continuing the experiments in a more careful manner in the hot weather, but was unable to carry out this idea. It was said at Pátri that the water rose much higher in the wells in the hot weather than in the cold, and this would certainly indicate tidal influence, as the periodical rise of water in the Ran in that season would certainly produce that effect, did subterraneous filtration exist to the extent supposed.

"On the other hand, at Kura, very much nearer the sea, the water in the wells is said to be very much lower in the hot weather than at any other time; but it may be said that the 'morod' underlying the Kura wells would prevent the influence of the tidal wave being felt there."

Flooding of the Lesser Ran from May to September.

From what has been stated, it will be observed that nearly all the writers about the Lesser Ran have at once jumped to the conclusion that the flooding of the Ran during the south-west monsoon months is almost entirely caused by the heaping up of the water of the Gulf of Cutch during that time. The writer has made a further analysis of the tidal observations at Hansthal, to see how far this idea is borne out by facts. During the month of July, the mean level of the water, as taken by averaging each 24 hours heights for the month of July, was found to range—

for July, from 5 inches below to 9 inches above the mean level of the year.
,, August, 4 ,, ,, 10 ,, ,, ,, ,,
,, September, 4 ,, ,, 1 foot ,, ,, ,,

Now this would hardly appear to justify the opinion that the Lesser Ran is entirely flooded by the water of the Gulf being ponded up and conveyed to the Ran by the Hansthal, Kundlo, and Nakti creeks.

One interesting result of the levelling operations taken by Captain Baird is, that the mean value of the level of the Ran between Mália and Shikárpur is only 6·781 feet above the mean level of the sea, while between Hansthal, Bálumba, and Jodiya the general level of the Ran is about 2 feet 9 inches higher. Now, the high tide in the cold weather rises at Hansthal frequently to 8 and sometimes to 9 feet, above mean sea level, and yet the Ran between Mália and Shikárpur is, as a rule, perfectly dry from November till March. This shows that there must be a considerable rise in the level of the Ran between Mália-Shikárpur and the head of the Hansthal Creek.

Then again, in levelling across from the Cutch side to the Chorár, in January 1876, there was from one to two feet of water on the Ran, while the line Shikárpur-Mália was perfectly dry, and there was found to be a depression of about two feet in the centre of the Ran, between Cutch and the Chorár.

The writer is under the impression that the following is the proper solution of the flooding of the Lesser Ran. There are certainly very high tides during the south-west monsoon, and when these happen to be sufficiently high, the sea water of the Gulf is carried over the sort of rise in the Ran noted above, and thus the water is

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allowed to flow on to the line joining Mália-Shikárpur and beyond towards the Choár, to fill up the shallow basin which the Ran forms, all about them. Then again, the Banás and other rivers being in flood, their waters are discharged into the Ran; the similar very high water in the July, August, and September high tides causes the Larger Ran to be covered with water at those times, communicating with the Lesser Ran between Cutch and the Chorár, and in this way such an amount of water is thrown into the Lesser Ran that the Hansthal, Nakti, and Khundlo creeks *do not afford sufficient capacity for its complete discharge into the Gulf at the low tides occurring at the moon's quarters.*

Thus a sort of inner sea is formed beyond the Hansthal Creek, which during the south-west monsoon may be said to cover the entire Ran, but during the cold weather is of very small size. It is obvious that the rise in the Ran which must occur between the line Shikárpur-Mália and the line Vavnya-Butcháo must be sufficiently high to prevent the ordinary high spring tides overflowing it, and thus during the cold weather, beyond this barrier, all the Ran to the north and east is being gradually dried up, the last portion of the Lesser Ran to dry up being that shallow basin near the Chorár.

This is further supported by the fact that between Hansthal tidal station at the mouth of the creek and Bálamba and Jodiya, the Ran was never covered with water except at extraordinary high tides, even during the monsoon.

The flow of the Machhu River into the Ran.

The Machhu river divides into several streams about 1½ mile north of Mália before falling into the Ran; the flow of its water when in the Ran is very slow, so that it does not erode the Ran bottom, but rather deposits "Kamp" or silt. The water flows to the south-west close to the coast of the Ran, and if a large quantity of water is discharged, the pool so formed reaches the Vavnya Creek after passing Bagasra and Tonk. The discharge from the river mouths ceases to flow by the end of November or the beginning of December; and by the end of December the broad expanse of water on the Ran begins to dry up. During the monsoon the ebb tide at the Hansthal Creek is held back by the strong westerly wind, and this coupled with the discharge of the floods of the Banás, Machhu, and Jhálávád rivers, causes the entire inundation of the Lesser Ran.

Two Creeks on the Ran N. E. of the Hansthal Creek.

There are two creeks on the Ran between Vavnya and the Cutch coast. That nearer the Cutch coast is called Wágardhrái and the other is called Chhách. In the former the tide rushes in with great force and in ebb washes away a considerable amount of land; the extremity of this creek towards the N. E. reaches to nearly 3 miles from Shikárpur in Cutch. At high spring tides the water overflows the banks of this creek and covers a great deal of the adjacent Ran. The water in this creek is from 10 to 12 feet deep at low water and the width from 500 to 600 feet, both banks steep. It must of course be crossed by a boat.

The Chhách Creek reaches to about 2 miles east of the line Bagasra-Jhingi; its encroachment on the Ran land is not so fast

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as that of the Wágardhrái Creek, but it is said its gradual encroachment commenced 30 or 40 years ago. This creek lies about 8 miles west of the mouths of the Machhu river, and the space between that portion of the Ran usually covered by the high water from this creek, and the flood of the Machhu is slightly elevated.

Encroachment of the Sea.

That the sea is encroaching in various portions of the Ran, the writer considers undoubted; but this, it would seem, only occurs where there are large creeks or channels discharging into the Gulf. Thus the Vavnya Bandar, and the bandar, or the landing-place, at Jhingi on the Cutch side, are now easier of access than formerly; the writer has crossed by boat during the monsoon from Vavnya to Jhingi, and nowhere, even at low tide, did there appear to be less than 3 feet of water.

Then again, the widening of the Hansthal Creek by the rush of the tide past the banks is most apparent even since the tidal observatory was constructed there; the banks of the creek have been worn away to a very considerable extent, which is certainly not to be wondered at, considering that the water rushes past with a velocity of 6 or 7 miles per hour. Moreover, the fact of the great amount of water annually held up during the south-west monsoon in that portion of the Lesser Ran west of Mália-Shikárpur having to be discharged into the gulf proper nearly entirely by the Hansthal Creek, must keep up this rush past the banks until the whole creek is very much enlarged.

Further evidence of the encroachment of the sea into the Ran is found from the routes of the postal runners from Káthiáwár to Cutch having had to be constantly moved eastwards.

The present Postal Route.

The present route for the post is from Tonk, about 3 miles north of Vavnya, on the Káthiáwár coast. Runners go from this place over the Ran until they reach the Chhách Creek, which at low tide is almost dry. Two miles beyond, towards Cutch, another creek has to be crossed: this is called the Wághardrái Creek, and here there is always water at all states of the tides. This creek is close to Jhingi and is really a branch of the Khundlo Creek. Boats are kept for the post-runners to cross these creeks. This dâk line was laid down about 1866. Formerly the line was from Vavnya *viâ* Tonk to Markania—that is, about 1 mile west of the present route. There is also evidence of the postal routes between Káthiáwár and Cutch having been still further west, *viz.*, from Khári Rohar.

On the Ran, between Jodiya and Hansthal stations, were found the remains of two postal chowkies,—one merely a small heap of mud and a few broken tiles; the other also a heap of mud, and close beside it a great many large bones, probably of a huge alligator, and this was called "Hadda-ka-chowki." From information Captain Baird got at Jodiya, it would appear that some 30 years ago the postal route to Cutch was from Jodiya over the Ran past the two chowkies above mentioned, thence to the Hansthal Creek, and crossing it in a boat, the runners went on foot over Sathsaida Bet, and then crossing the Khundlo and Nakti Creeks, they reached Cutch.

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Routes and passes across the Ran near Mália.

The Ran is crossed from the following places in Káthiáwár, to the following places in Cutch:

(1) Mália by Kanjarda and the Lákhiásar Tank in Káthiáwár to Shikárpur and Mánaba in Cutch.

(2) From Venásar in Káthiáwár to Kánmir and Palánswa in Cutch.

(3) From Tikar in Káthiáwár to Palánswa and Rámpur in Cutch.

The road from Lákhiásar Tank to Shikárpur and Mánaba is direct, but Palánswa can be reached by a circuitous route. Camels and horses *can* cross the Ran by this pass at all seasons, but carts can only cross in the dry season. In the rainy season travelling on horseback is very dangerous, and boats are almost invariably used instead. It is difficult to assign an exact date when this pass is open to carts, but, as a rule, December 1st is the earliest date on which carts can cross from Lákhiásar Tank to Shikárpur and Mánaba.

The Venásar pass being higher up the Ran it takes a longer time before becoming passable, and the Lákhiásar pass is the first one to dry. There is however even by the Lákhiásar pass a space of about 1000 feet wide towards the middle of the Ran where water lies until December is past. The westerly wind covers the Lákhiásar pass with sea water by March 20th, and the Venásar pass is covered by April 24th. The water reaches Tikár by May 31st, after this the Ran is only crossed by boat.

The village of Nanda (north of Bhurran Wáo Mahádev, and about north-east of Palánswa in Cutch) which is an island in the Ran and not far from Palánswa. Tikar road is by the 31st May entirely covered by water.

Old route Mália to Wándhia.

Formerly there was a road from Mália to Wándhia (in Cutch), but during the last 10 years, it has been closed by the encroachment of the channel formed by the sea called the "Wágardhrái Nes".

There is no pass across the Ran from either Barál Jajasar, Bagasra and other Morbi villages, and now the Lákhiásar route is the only practicable one.[1]

Ancient route from Bálamba in Káthiáwár to Jhingi in Cutch.

[1] The Navánagar Darbár have supplied information regarding this ancient route, as follows: "His Highness the late Mahárája Jám Shri Rávalji crossed the Ran from Jhingi on the Cutch side to Bálamba on the Hálár coast by the footpath called 'Sathserda', and this appears to be the present creek of Hansthal which was then dry land and could be crossed by footmen and horses."

The following statement shows what villages on the opposite coasts (*i.e.* Cutch, Pálanpur, and Rádhanpur) of the Ran are reached from those of the Dhrángadra State on the Káthiáwár coast, the approximate time when the roads are covered with water, and the average period during which it remains, also the probable time when the roads are open to carts, &c.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
						Measurement of depth of water in feet and inches.			Probable date when water begins to dry.		Distance between villages in miles.					
Names of villages of the Dhrángadra State bordering on the Ran.	Names of Cutch, &c., villages that are reached from villages in Column 1.	Names of States to which the villages of Column 2 belong.	Approximate dates when the water begins to enter the Ran.	Approximate dates when the roads for camels, horses, and footmen are open.	Approximate dates when the roads are open for carts.	Depth of water before rain falls.	Depth during the rains.	Depth when Bands is in flood.	Date when water begins to dry.	Date when roads become passable.	Length of the fore-shore of the Ran.	Length of the water surface of the Ran.	Length of dry land, island, &c.	Total of miles.	Number of islands.	REMARKS.
Navu Ghántilu	Gagudad*	Cutch	24th April	Always	18th Nov.	1¼	3-3½	5·6	24th Oct.	18th Nov	6	14	3	23	2	* This village is also reached from Tikar.
Tikar	1 Palánswa	Do.	Do.	Do.	Do.	1¼	3-3½	5·6	Do.	Do.	9	14	3	26	2	
Do.	2 Kánmir	Do.	Do.	Do.	Do.	1¼	3-3½	5·6	Do.	Do.	9	14	3	26	2	
Do.	3 A desar	Do.	Do.	Do.	Do.	1¼	3-3½	5·6	Do.	Do.	18	19	3	40	2	
Do.	4 Gagudad	Do.	Do.	Do.	Do.	1¼	3-3½	5·6	Do.	Do.	10	12	3	25	2	
Khod	All the villages noted above.	Do.	Do.	Do.	Do.	1¼	3-3½	5·6	Do.	Do.	Do.	Do.	Do.	Do.	2	This road joins the road passing from Tikar and that from Keshmál island, and becomes one main road.
Jogad		Do.	Do.	Do.	Do.	1¼	3-3½	5·6	Do.	Do.	Do.	Do.	Do.	Do.	2	
Do.	Jhinjúváda	Jhinjúváda.	26th May.	24th Oct.	Do.	½	2·0	4·0	Do.	Do.	8	29	3	40	1	This pass lies across a great breadth of water and is therefore at all times difficult in the rains.
Do.	Odú	Do.	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	8	29	3	40	1	
Do.	Amrápur	Várái	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	9	29	3	41	1	
Do	Kordha	Rádhanpur.	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	9	29	3	41	1	
Do.	Piprála	Cutch	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	6	28	...	34	...	
Málaniád	Jhinjúváda and those named above	Do.	Do.	Do.	Do.	½	2·0	4·0	Do	Do.	6	28	...	34	...	
Eujál		Do.	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	Do.	Do.	Do.	Do.	Do.	
Koparni	Do.	Do.	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	Do.	Do.	Do.	Do.	Do.	
Kuda	Do.	Do.	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	Do.	Do.	Do.	Do.	Do.	
Naráli	Do.	Do.	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	Do.	Do.	Do.	Do.	Do.	
Jeshda	Do.	Do.	Do.	Do.	Do.	½	2·0	4·0	Do.	Do.	Do.	Do.	Do.	Do.	Do.	
Málwan	Odú	Jhinjúváda.	21st June.	Do.	Do.	...	2·0	4·0	Do.	Do.	4	6	...	10	...	The Ran here is not covered with sea water, but only with rain and flood water which mixes with the sea water.
Do.	Jhinjúváda	Do.	Do.	Do.	Do.	...	2·0	4·0	Do.	Do.	5	6	...	11	..	
Thala	Ditto and Odú	Do.	Do.	Do.	Do.	...	2·0	4·0	Do.	Do.	Do.	Do.	Do.	Do.	Do.	
Sultánpur	Do.	Do.	Do	Do.	Do.	...	2·0	4·0	Do.	Do.	Do.	Do.	Do.	Do.	Do.	

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As the routes from the villages of Navu Ghántiú, Tikar, Khod, Jogad, Jeshda, Málvan, Thala, and Sultánpur in the Dhrángadra State are passable *after* the Ran is partially covered by water, it is necessary to give some account of them in detail. The routes from the remaining villages of the Dhrángadra State mentioned in the above statement are rendered impassable during the S.W. monsoon on account of the Ran being very broad and its bed very swampy (though it is covered with but little water) and even although the water reaches this portion of the Ran later in the monsoon than the western portion.

The roads from Tikar to Ádesar, Palánswa, and Kánmir are ordinarily used, they are always open except when the river Banás is flooded. The distance between Tikar and Ádesar is 40 miles, the Ran portion being 22 miles; this part of the Ran is divided into 3 parts or channels by 2 ridges near its centre and the coasts on either sides. The first channel commences at a distance of 6 miles from Tikar and holds a little water during the S. W. monsoon for a breadth of about 6 miles, then comes the ridge called Bhangoria about 1 mile in width. The channel above described begins to receive the water forced up the Gulf of Cutch about May, and the water rises to a height of about 15 inches, and afterwards, when the rain has actually fallen, the water rises to 3 or 3½ feet; the water does not begin to dry up until about middle or end of October. Sometimes, when the Banás is in flood, water rises to 6 or 7 feet, and remains so for perhaps 8 or 10 days.

After crossing the channel and ridge above described, we come to another channel of about 8 miles in width which is influenced by the monsoon rains in a similar way, but is rather more shallow and thus the water does not lie so deep. Beyond this channel is an island called "Mardok" about 2 miles broad, which contains a few pools of sweet water and a small tank. There is also a temple of "Varnû" on this island. Beyond this is another channel of the Ran about 5 miles broad and having a depth of water in the monsoon similar to the other channels.

The road from Tikar to Palánswa enters the Ran 6 miles from Tikar and crosses the first channel on the Ran above described, then we come to the island of Keshmál about 1½ miles broad, then the road crosses the second channel of the Ran to the island of "Gunya" about a mile and half broad and containing wells of sweet water; beyond this the Ran is 2 miles broad and having about a foot of water in it during the monsoon and about 3 feet when the Banás is in flood.

The road from Tikar to Kánmir is the same as that to Palánswa as far as the island of Gunya where it branches off to the left.

The Ran is crossed from Sultánpur and Málvan to Odú and Jhinjúváda, but the sea water does not reach as far as this portion of the Ran, which, however, is covered by rain water to a depth of about 2 feet or perhaps 4 feet when the Banás is in flood. The roads from Jogad which lead to the Chorár and to Amrápur as also those from Málaniád, Eujál, Koparni, Kuda, and Naráli are impassable from the beginning of May till November.

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After some correspondence on the subject, the Superintendent, Great Trigonometrical Survey, was requested to arrange that a complete series of observations should be taken at certain selected points on the Gulf of Cutch. It was proposed to have at least three points,—one at the mouth of the Gulf, one as far into the Ran as possible, and a third midway between if possible; and that a series of carefully-executed levels should be made between the stations. It was proposed to repeat the observations some years after, and then the question of the secular change in the Ran might be satisfactorily settled.

A detailed account of the operations may now be given, and the following is a reprint of the compilation, by Captain Waterhouse, Assistant Surveyor-General, of the Great Trigonometrical Survey reports, which Captain Baird submitted from time to time, and also of portions of the Surveyor-General's annual reports.

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APPENDIX.

An Account of the Tidal Observations in the Gulf of Cutch, conducted by Captain Baird, R.E., of the Great Trigonometrical Survey, under the Superintendence of COLONEL J. T. WALKER, C.B., R.E., *during the years* 1873-74-75. *Compiled from the G. T. Survey Reports by* CAPTAIN J. WATERHOUSE, *Assistant Surveyor-General.*

Origin and Object of the Observations.—In his Report on the Operations of the Great Trigonometrical Survey for 1866-67, Col. Walker writes:

> "Dr. Oldham, the Superintendent of the Geological Survey of India, has recently drawn the attention of the Government to certain questions which have been raised regarding secular changes in the relative level of the land and sea, which are believed to be going on in various parts of the Bombay Presidency, and more particularly at the head of the Gulf which separates the province of Cutch from that of Káthiáwár. Dr. Oldham recommends that certain points should be selected on the south coast of Káthiáwár, and as far up the Gulf as possible, and that the existing relative levels of land and sea should be determined at those points by accurate tidal observations carried over as long a period as possible, the tidal stations being connected by lines of levels. Thus, by repeating the operations at a time sufficiently distant to allow the secular changes to reach an appreciable magnitude, this question, which is of much scientific importance, will be satisfactorily settled."

The Government of India sanctioned the observations being made, and Col. Walker was making arrangements for carrying them out, when a very considerable reduction in the expenditure of the Survey Department, in consequence of the financial difficulties in 1869-70, caused the indefinite postponement of the operations. It was not until August 1872 that steps could be taken for commencing them.

The delay which thus took place is, however, not to be regretted, because it resulted in the investigations being carried on in a more complete and elaborate manner than had been originally contemplated, with a view to acquiring more comprehensive and accurate results than were at first desired.

Happening to be present at the Meeting (in Edinburgh) of the British Association in 1871, Colonel Walker ascertained that a Committee of the Association, presided over by Sir William Thomson, had initiated a system of tidal investigations which was anticipated to secure scientific results of the highest value. On studying the details of these operations he found that his original programme, which contemplated tidal observations of only a few weeks' duration, would be inadequate to detect the existence of minute secular changes in the relations of land and sea, and that no conclusive results could be obtained unless the observations were carried over a period of rather more than a year at the commencement, and a corresponding period at the close of the investigation. He further saw that if this were done, the value of the operations would be greatly increased, because the results would not only serve the purpose for which they were originally contemplated, but would materially contribute towards the

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attainment of the better knowledge of the law of the tides, which is considered by the British Association to be so important a desideratum, and which is expected to lead to an evaluation of the mass of the moon, to definite information regarding the rigidity of the earth, to an approximation of the depth of the sea from the observed velocities of tide-waves, to the determination of the retardation of the earth's rotation due to tidal friction, and also to the various practical benefits which necessarily accrue from accurate predictions of the height of the tide at any given time.

Preliminary Preparations.—With the sanction of the Secretary of State for India, Lieut. (now Captain) A. W. Baird, R.E., Assistant Superintendent G. T. Survey, who was then in England on furlough, was deputed to study the practical details of the mode of tidal registration and of the harmonic analysis of the observations, which were recommended and practised by the Tidal Committee of the British Association.

Lieut. Baird also tested at Chatham a new self-registering tide-gauge constructed by Adie the well known optician and mathematical instrument maker, on the same principle as those he had previously sent out to India, which were provided with barrels of unusual length (five feet) in order that the tidal curves might be drawn on the largest scales practicable. The new tide-gauge was on the same pattern, but with a few modifications, the most important of which was the substitution of a chronometer escapement instead of a pendulum or gravity escapement for the driving clock, in order to permit of the instrument being erected on positions where the concussions of the sea waves would interfere with and perhaps stop the action of a pendulum clock. On trial it was found to work very satisfactorily.

No tidal registrations can be deemed complete without simultaneous registrations of the condition of the atmosphere, because it is well known that the rise and fall of the tides on a line of coast is materially influenced by the direction and force of the winds, and that it also varies inversely with changes in the barometric pressure. Arrangements were therefore made for supplying each tidal station with an anemometer and a barometer, both self-recording. The anemometers registered both direction and velocity and were similar to Beckley's, but smaller, in order to be light and portable. The barometers were aneroides, because safely portable self-registering mercurial barometers could not be obtained.

Selection of Stations.—On Col. Walker's return to India, in November 1872, he deputed Lieut. Baird to make a reconnaisance of the Gulf of Cutch, with a view to selecting tidal stations, and more particularly to ascertain how the instructions which had been received from the Government to establish a station "at a point as far into the Ran of Cutch as possible to which the tide has free access" could be best carried out. For a point to have free access with the sea it is necessary that it should always have at least 4 or 5 feet of water over it at lowest tides, and also that the sea should approach it directly, and not through tortuous channels; the point must also be either on the edge of the mainland or at no great distance beyond, because of the difficulty and expense of constructing a station on the foreshore. It seemed not improbable that it might not be possible to find a point at the edge of the Ran which would satisfy all the requisite conditions.

Lieut. Baird proceeded first to Jodiya Bandar, close to the head of the Gulf, where he fitted up a country boat for navigating the creeks and channels of the Gulf, and secured the services of an experienced pilot to accompany him in his explorations. After a month's cruising about and long searching along the muddy foreshores of the Gulf, three places well adapted for tidal observations were found. 1st, Nawanár Point, midway up the Gulf on the Cutch coast, 15 miles from Mundra; 2nd, Hansthal Point at the head of the Gulf, about 18 miles from Jodiya; and 3rd, Okha Point on the Káthiáwár coast, just at the mouth of the Gulf, opposite the island of Bet. At Nawanár there was a minimum depth of 19 feet of water within 336 feet of a site for a station; at Hansthal 72 feet within 160 feet of a site for a station, and at Okha 23 feet within 220 feet of a site for a station. Nawanár is about 9 or 10 and Hansthal 16 miles from the nearest village where drinking water can be procured; Okha Point has Bet within 1 mile, but a boat is required for communication with it.

The three places selected were considered to be well adapted for the operations, which was the more fortunate in that Lieut. Baird believed them to be the only suitable points to be met with for the purpose. It is to be regretted, however, that an intermediate point could not be found on the Káthiáwár coast, between Okha and Hansthal, for Nawanár being on the opposite coast had to be connected with the other two stations by a very long line of levels passing round the head of the Gulf; and, as it afterwards turned out, Nawanár proved unsuitable by constant changes in the configuration of the foreshore.

Preliminary arrangements.—The stations having been selected, preliminary arrangements were commenced.

The first question to be decided was whether the tide-gauges should be set up on stages erected in the sea beyond the low-water line, or on masonry platforms constructed on shore at the high-water line. It is obviously desirable that the communication between the surface of the ocean and the gauge should be as direct as possible, in order that the tidal curve may be accurately delineated. Thus, it is usual to erect tide-gauges in ports or harbours where the piers, quays, and landing-stages constructed for the requirements of the shipping present facilities for their being set up in the vicinity of deep water. In the Gulf of Cutch, however, the stations were all at a distance from the nearest inhabited localities and presented no facilities whatever; for not only building materials and food for the workmen, but even fresh water, had to be brought to them from considerable distances. It was thus imperative that the plan of operations should be of the simplest nature possible, so as to be carried out with the least cost and the greatest expedition. Had any jetties or piers been available for the operations the stations would have been erected on them, but under existing circumstances it was only possible to connect the tide-gauges with deep water by erecting stagings for them in the sea; and these would have had to be very strongly built to withstand the full force of the sea, without undergoing any displacement whatever, and that, not for a short time only, but for several years, so as to include both the first series of tidal registrations, taken to determine the present relations of the land and sea, and the final series which will have to be taken to determine the future relations some years hence. The stagings would, moreover, have had to be connected with the land by piers, in order to permit of ready access to the instruments at all times. The cost of such stagings and their connecting piers would have far exceeded the funds available, and therefore Col. Walker decided, though with some reluctance, on having the tide-gauges set up on shore, over wells sunk near the high-water line and connected with the sea by piping.

Final arrangements.—The following is a brief sketch of the arrangements adopted:

Masonry wells of a diameter of about 3 feet were sunk at the stations to a depth of several feet below the lowest tides; in these wells iron cylinders with an internal diameter of 22 inches, slightly exceeding the diameter of the float of the tide-gauge, were set up vertically and connected with the sea by an iron piping carried along the shore down to the low-water line, where a flexible piping was attached and carried out into deep water. The flexible piping terminated in a rose suspended by means of buoys a few feet above the bed of the sea, in order to prevent the entrance of silt as much as possible, and was attached to the iron piping in such a manner that it might be readily removed and cleaned whenever necessary. The tide-gauges were set up over the cylinders, and their iron bed-plates indicated the planes to which the tidal measurements were referred; they were connected by levelling with permanent bench-marks fixed in the ground in the vicinity of the stations.

The iron cylinders were made up in sections of 50 inches in length, a sheet of wrought-iron being bent to the size required and rivetted to form a cylinder, a cast-iron flange was fitted on to each end and the faces of these carefully turned so as to fit exactly. The bottom section had a flat iron plate carefully screwed on to one end, so as to form the bottom of the well, and the whole when bolted together formed a water-tight well into which water could only enter through the piping connecting it with the sea. The size of the cylinders was decided on so as to utilise the iron sheets most economically, and when finished four men could carry one section. Before being let into the wells they were well painted over, inside and outside, with tar in order to keep them from rusting. The level of the top flange of the cylinder was about 6 feet above high-water spring tide, and about 2 feet 6 inches above the floor of the observatory. A board fitted on and screwed to the top of the cylinder, with holes for the float bands to pass through, prevented anything falling accidentally inside the cylinder.

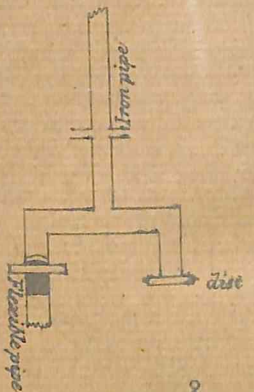
The rigid iron piping was ordinary gas-pipe in lengths of about 14 feet, with an internal diameter of 2 inches, which had been computed to be sufficient to permit of the transmission of the tidal wave from the sea to the cylinder in the well without sensible retardation, so that the height of the water in the cylinder should always be the same as that of the surface of the sea. In order to render the connections perfectly water-tight, as well as to facilitate the joining together of the lengths of piping, these were fitted with cast-iron flanges made to screw on to each end.

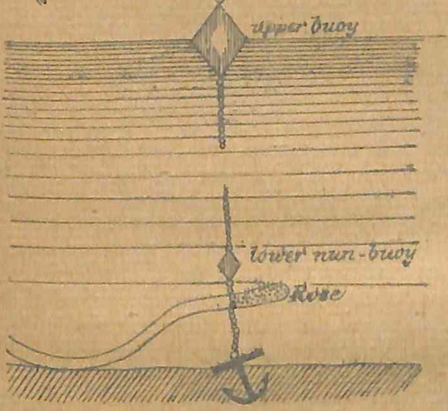
The piping was connected with the bottom of the cylinder, at 9 inches above it, by a small bend, and was then brought up vertically outside the cylinder to a height 1 or 2 feet below the lowest high-water. At this point was another bend with a stop-cock in it, and the pipe was then taken straight out down to the sea along the slope of the shore to reach low-water springs.

The rigid and flexible pipes were connected together by means of the following arrangement:

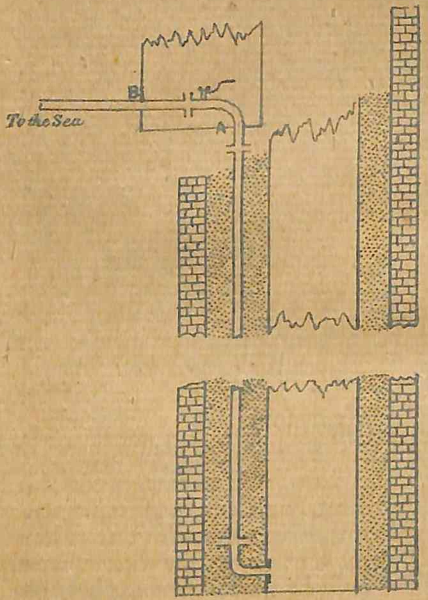
To the end of the rigid iron pipe a brass connecting piece, made as shown in the figure, was fitted, having two outer extremities, to one of which a flexible two-inch suction-pipe was fixed and the other closed by a brass disc with a good washer. When the flexible pipe had to be examined for cleaning, the brass disc was unscrewed and a short length of spare flexible piping with a rose at its end fitted on, and taken out to deep water temporarily. The original pipe was then taken off and cleaned, the disc being screwed on for the time in its place; then when finished the long pipe and disc were replaced in their original positions. The flexible pipe was two inches in diameter with copper inside, just the same as the suction-pipe. It was provided in lengths of 50 or 60 feet, and in smaller ones of 20 feet for temporary use only. The lengths were fitted with couplings and unions for connecting them with each other.

Lengths of this suction-pipe were joined on to the end of the iron piping in the manner above described, and taken out to deep water. At the end of the outer length a copper rose, of about 15 inches in length, 2 inches in diameter, and having about 150 holes of $\frac{3}{10}$ of an inch bored in it, was screwed on. This rose was sustained a few feet from the bottom, being attached to a small nun-buoy by a chain and shackle with swivel, the whole being held in position in deep water by an anchor. To the top of the small nun-buoy a chain was attached, to which was fixed the large buoy floating on the surface, with plenty of slack chain to allow for rise and fall of tide, and this buoy also served to mark the position of the flexible pipe. The arrangement will be understood by reference to the annexed figure.





The level of the water in the well should obviously always coincide with that of the sea, otherwise the registrations of the gauge are worthless; it is therefore imperatively necessary to compare the inside and outside levels from time to time, in order to remove all doubt as to the efficiency of the communication between the well and the sea. For this purpose an ordinary gauge was attached to a pile driven into the bed of the sea, and its zero was connected with that of the self-registering gauge over the well, by spirit levelling, and thus a comparison of the levels could be readily made whenever desirable. On taking these comparisons during certain trial observations at Bombay, Captain Baird was surprised to find that while the levels were generally identical, there were occasional large differences which at first could not be accounted for; eventually, however, he succeeded in tracing them to the accidental presence of air inside the piping. He soon devised a simple method of expelling the air and restoring the requisite identity of level, by fixing a stop-cock for the exit of the air at the vertical bend, where the iron piping, after rising from the bottom of the well to within a few inches of the surface of the ground, begins to slope downwards towards the sea. This bend has necessarily to be made at a point a little below the level of the lowest high-water tide, and, consequently, on opening the stop-cock at high-water, all the air inside the pipe is of course immediately expelled, and then the water inside the well at once assumes the same level as that of the sea. But for this expedient it would have been impossible to carry on the operations continuously for any length of time, as there was found to be a decided tendency for air to collect in the pipes. It was most fortunate that this was discovered during the experimental observations at Bombay, for there stop-cocks could be readily constructed and attached to the piping, which could not possibly have been done at either of the stations in the Gulf.



At Okha Captain Baird found some difficulty in keeping the stop-cock dry and having access to it. He therefore had a water-tight box 3 feet long and 1 foot square made in halves and fitted over and under the stop-cock, holes having been cut to admit the pipes, and carefully caulked up after the box had been fitted over the pipe (see figure); in this way no water could get at the stop-cock except over the top of the box. Underneath the first 7 or 8 feet of the pipe leading to the sea, a layer of mud and stones of considerable thickness was made, and a wall of similar material built all round the stop-cock, leaving a space about 3 feet square for standing in and steps for getting down to it; also mud and sand were thrown down between the iron cylinder and the masonry wall right up to the level of the stop-cock bend. It was found that by this means the stop-cock was quite dry and access could be had to it at any time however high the tide was.

Captain Baird spent the recess of 1873 at Bombay in preparing for the operations of the field season of 1873-74. Cylinders as above described were constructed in suitable lengths to be easily transported to the tidal stations and there put together. The several self-registering instruments which were to be employed—the tide-gauges, the aneroid barometers and the anemometers or anemographs—were overhauled and put into good working order. The tide-gauges were tested by being employed to register the tides in the harbour of Bombay for several weeks continuously, and were set up over wells connected with deep water by piping, in order that the experimental observations should be taken under precisely similar circumstances to the actual observations. Sundry alterations and improvements were made in them, and in fact everything was done which could be thought of to ensure the instruments being found in a satisfactory condition when they were set up for work at the tidal stations. It was a matter of great importance to have all this done at Bombay, because the advantages of excellent workshops and skilled artificers were not to be met with in the places where the instruments had to be set up for observation.

While in Bombay, Capt. Baird also constructed three portable observatories for erection at the tidal stations. These observatories were made in such a manner as to be readily put together, or taken to pieces and re-erected at any other place where they might afterwards be required. They were about 12′ × 9′ × 9′ and about 12 feet high in the centre, the roof sloping from the ridge to the sides which were about 8 feet high. They were clinker-built, but it was found necessary to cover them with a tarpaulin to keep out the heavy rain during the monsoons.

Operations at Okha Station.—Okha station being near the mouth of the Gulf and the nearest to Bombay, where all the preliminary arrangements were made, was selected as the first to be taken in hand. There all

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the instruments and stores, and the European assistants, including Mr. Peters, a skilled artificer of the Bombay Harbour Works, whose services had been obligingly placed at Capt. Baird's disposal by Major Merewether, R.E., 6 sub-surveyors and 24 men were sent, on the 13th October 1873, direct from Bombay in a large *pattimar* (or native sailing vessel). Meeting with contrary winds, the "Kotia Romani" took such a long time to perform the voyage that Capt. Baird began to fear that she was lost with all hands on board; at last, however, she arrived with her passengers and crew nearly starved, for they had only taken a week's provisions for a voyage which lasted a fortnight. On the 5th November the stores were landed and the first thing to be done was to make an excavation for the iron cylinder. At Okha, as well as at Nawanár, the soil being sandy, it was necessary to take measures to prevent the sides of the well from falling in during the excavation, and therefore a masonry well of sufficient diameter to receive the iron cylinder and vertical shaft of the piping had to be sunk in much the same manner as the wells so frequently used in this country for the foundations of bridges and aqueducts. The operations were considerably facilitated by the employment of Bull's Patent Dredgers for scooping out the soil under the sinking masonry. (At Hansthal, where the soil was firm, the masonry well was unnecessary). The masonry well was completed to the full depth of 25 feet by the 4th December, and by the 20th the cylinder had been set up, the piping connected with the sea had been laid out into deep water, the observatory was erected and the several self-registering instruments—a tide-gauge, an anemometer and an aneroid barometer—were all in position and ready for the preliminary trial of their performances. By the 23rd everything was complete, the instruments were all working well, and Capt. Baird was about to proceed to the next station, when an accident happened through a native boat drifting down past the station about 3 in the morning of the 24th December, and dragging her anchors across the flexible pipe, smashing it and carrying off a large portion of it as well as the buoys, anchors, &c. Being on the spot, Capt. Baird was able to rectify the damage and to arrange for protecting the piping by laying out and anchoring hawsers around it. Guards were also provided to prevent boats from approaching the buoys. Thus this accident, though very annoying at the time, proved of use in showing the necessity of taking special precautions for the protection of the piping from injury. Similar measures were taken at the other stations, and these precautions were essential to the success of the operations, because in case of any similar accident happening to injure the piping, the native subordinate who would ordinarily be left in sole charge of the station to keep the instruments in order and look after their performances, would be unable to repair the damage without the personal help of Capt. Baird, or the European assistant, to obtain which would probably cause suspension of the tidal registrations for a fortnight or more, and greatly impair the value of the observations.

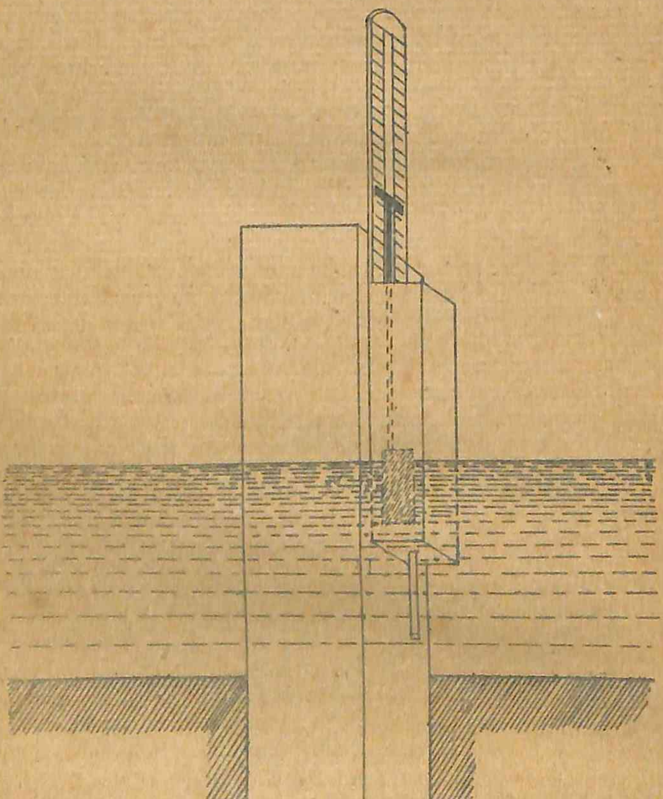
While engaged in completing the arrangements at Okha, Capt. Baird sent his assistants in advance to Hansthal and Nawanár to sink the wells, erect the observatories and get everything ready for him to set up the instruments.

The observatory at Okha was fixed on three cross-beams fitted on the tops of six large piles embedded 8 feet in the sand. The cylinder was about 2 feet from the eastern end, the tide-gauge being of course as nearly as possible in the centre of the building. The aneroid barometer was placed carefully on a shelf at one corner. The anemometer was fixed to a shelf so that the upright pipe passed through the roof close to the ridge at the western end (the rain-gauge being close to it on the outside). A platform was made to get at the anemometer easily, and this served a double purpose, as it was also the framework for a guard to protect the pendulum and clock of the tide-gauge, and cloth having been fixed all round it, kept any wind from getting to the pendulum.

The self-registering tide-gauge was carefully so placed that the band allowed the float to be 3 inches from one side of the cylinder, while it was the same distance itself from the other side. The instrument having been carefully levelled by wedges, the trestle was secured with screws to the floor ; a hole was cut in the floor and a small box let down (properly fitted so as to allow no sand to come in), in order that the counterpoise weight might be able to act for the entire range of the instrument.

The float band was made 35 feet 6 inches long and 33 feet of chain was added to this, and fixed at its other end to the hook under the float, forming a continuous band as it were. The scale of wheels adopted here was $\frac{1}{4}$; the barrel being 5 feet long, that scale was the largest that could be used for a 14·90 feet range of tide. The float had a swivel to which the band was attached, and the band also passed through two guides fixed to an upright scale on one side, and through another guide fixed to the trestle on the other.

The temporary tide-gauge, consisting of a pile firmly imbedded in the sand and standing about 8 feet out of the ground, was placed about the



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level of low-water neaps; to this was attached a box containing a copper float, and to the float was attached a deal rod with a pointer at the end of it about 6½ feet above the float. In the bottom of the box a pipe, two feet long, of small diameter was fixed so as to permit the sea to have access to the float; the box itself was about 6 inches square and 6 feet high, the side of it attached to the pile was extended upwards for 6 feet and had a grove in it in which the upright rod with the index worked (*vide* figure), so that by having this upper part numbered from a certain zero, the level of the sea below this zero could be at once read off. It was found by careful trial in a bucket of water that the pointer always recorded 6 feet 2 inches above the level of the water in which the float worked—the scale was made accordingly; levels were taken to connect the temporary tide-gauge with the top of the cylinder, for comparison of level of water inside and outside.

It will be unnecessary to enter into details of the operations at each station as they were similar to those at Okha, of which the principal outlines have been given. Full details will be found in Capt. Baird's report appended to the General Reports of the Great Trigonometrical Survey for 1873-74 and 1874-75.

Commencement and Progress of the Observations.—The regular tidal registrations were commenced at Okha by the end of December 1873, at Hansthal by the end of March 1874, and at Nawanár by the end of April. It was hoped that they might have been carried on continuously for at least a year, or perhaps longer, at each station, in order to furnish the requisite data for investigations of the separate influence of each as well as the combined of all the principal tidal constituents, and the least that is needed for this purpose is a series of observations extending over a year. During this time the errors of the clocks for driving the barrels of the self-registering instruments would have to be frequently determined and the clocks corrected; the instruments would also have to be examined and cleaned, and possibly repaired also, and the relations between the curves on the diagrams and their zero lines would have to be carefully re-determined from time to time; and all this would have to be done either by Capt. Baird, or by his assistant Mr. Rendell.

Capt. Baird, accordingly, drew up a programme for the periodic inspection of the stations, and arranged that he and Mr. Rendell should make tours of inspection in turn. It was calculated that a tour embracing all three stations would take about a month from the date of leaving to that of returning to recess quarters; these had been established in Rájkot, the nearest town to the Gulf, where house accommodation suitable for Europeans could be obtained. Anticipating that during the monsoon months the weather at the tidal stations might be found too cloudy to permit of astronomical observations for determining the clock errors, Capt. Baird provided himself with two portable chronometers which were rated at Rájkot and carried about on the tours of inspection, for comparison with the clocks.

Difficulties of the Operations.—The operations were carried on under many and great difficulties, and Captain Baird and his assistants incurred considerable risk when crossing the Gulf in native sailing vessels, as they frequently had to, whenever their presence was required at either of the stations. Huts had to be built and iron water-tanks provided at each station for the native subordinates who were placed in charge of the instruments, and for the men of the guard furnished by the Darbár of the Native State in which the station is situated. Arrangements also had to be made to supply these men with food and drinking water, which at Hansthal was no easy matter, for the nearest point whence these necessaries of life were procurable was about 25 miles off. At each station a

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line of post runners had to be established to the nearest points on the main line of postal communication, as it was essentially necessary that Captain Baird should receive daily reports from the men in charge of the observatories.

The inspection of the observatories necessitated a great deal of hard marching and entailed much exposure and privation. Even so early as in the month of May, before the setting in of the monsoon, the Ran of Cutch was covered with water, from six inches to a foot in depth, which had to be waded through for many miles distance to reach the station at Hansthal. At such seasons travellers usually cross the Ran by riding on the camels of the country; these animals are bred in large numbers along the borders of the Gulf, and are accustomed from their birth to wander about the swamps, browsing on the mangrove bushes, and thus they learn to walk with ease and keep their feet on ground which would be impossible to most other camels. Of his journey with Mr. Rendell, to Hansthal in the month of May, Captain Baird writes, "Our only land-marks in the "whole of the last 14 miles were two small mounds of earth thrown "up—when there were postal chowkies there—at 4 or 5 miles apart, and "the observatory itself; we both felt a curious sensation as if we were "being carried out to sea, which was occasioned by seeing small branches "of scrub floating on the surface of the water and being driven by the wind "inland; and once, with the exception of one of the mounds above men-"tioned in the distance, there were no fixed objects visible to destroy "this optical illusion." Later on, when the monsoon set in, the difficulties of locomotion were greatly increased; direct communication with Nawanár, by crossing the Gulf in a sailing boat, became impossible, as none but native vessels were available for the purpose, and they could not venture across in the strong gales then prevailing; and in order to reach that station a very long circuit had to be made round the head of the Gulf, crossing the Ran at its narrowest point opposite to Vavnya. Moreover, the common unmetalled roads in a black-soil country, as is the western portion of Káthiáwár, become all but impassable during the rains; and thus Captain Baird was often unable to get over the ground more expeditiously than at the rate of about a mile an hour. Between the 7th July and the 8th September he was actually 38 days in the field, and marched nearly 800 miles under most adverse circumstances.

General Working of the Tide-gauges.—The general working of the tide-gauges at the three stations has now to be noticed.

At Okha the registrations went on most satisfactorily throughout 1874 and the following field season; there were very few breaks of continuity of the records, and they were very short and of no importance. At Hansthal where the water was very muddy, and not pure and clear as at Okha, the breaks were more numerous and longer; they were caused sometimes by the driving clock getting out of order, but more frequently by the deposit of fine mud in the well and piping of the gauge, notwithstanding the precaution which had been taken to keep the rose at the extremity of the piping high above the mud-bank; this necessitated the occasional suspension of operations while the mud was being removed, and care was always taken to make the break between the times of high and low water, whenever possible; thus, as the record of the highest and lowest points of curves has been secured in almost all instances, the breaks may usually be interpolated between them by hand, in conformity with the collateral curves, without any risk of significant error. The foreshore at Okha being sand and rock without mud, there was no tendency there for the pipe to become choked. Both at Okha and at Hansthal air was found to enter the iron piping, whenever the latter was laid bare

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by the action of the surf, which frequently happened; but it was readily expelled at high-water, by opening the stop-cock which has already been described as attached to the piping for that purpose.

At Nawanár, matters went on less prosperously. When inspecting this station in July 1874, Captain Baird found everything apparently in good order; the curves on the diagram seemed at first to be all that could be desired, but it was soon evident that they were erroneous, for the level of the water in the well differed very sensibly from the sea level. On examining the piping, the extreme end was found to be buried in sand above the low-water line, at a spot where a few weeks before there had been a depth of 20 feet of water at low tide, but which was then left bare for some time daily. On further examination it was ascertained that the configuration of the foreshore had entirely changed, and an extensive sandspit had formed on the line of the piping; this had been caused by the drift from a belt of sand-hills to the south, under the influence of the strong winds which blew from the south-west during the monsoon, the registered velocities of which were 860 to 890 miles daily, for several days preceding the misadventure. This accident necessitated the suspension of the registrations at Nawanár until such time as the piping could be extracted and again put into communication with deep water. It was expected that the original configuration of the foreshore would probably be restored by natural causes, when the wind veered round to the usual direction, soon after the commencement of the cold-weather months; but this expectation was disappointed, and as the cold season wore on it became only too certain that the piping which lay beyond the low-water line would never be recovered. A supply of new piping was therefore obtained from Bombay and attached by Mr. Rendell to the land portion of the original pipe; and by the commencement of March 1875, after a break of 9 months' duration, the tide-gauge was once more in free communication with the sea, and there appeared to be every probability that it would so remain at least till the setting in of the next monsoon.

But within a fortnight after the re-starting of the tide-gauge at Nawanár, the foreshore again shallowed, and the new piping was covered with a deposit of silt and mud, nearly up to the level of the rose at its outer extremity. Mr. Rendell at once cut away the flexible piping and substituted several lengths of iron piping, supported by being attached to stakes driven vertically into the ground. By remaining on the spot for two months, taking measures to prevent the rose from being reached by the constantly rising mud and silt, Mr. Rendell succeeded in securing satisfactory and continuous readings for the whole of the time, and he checked them occasionally by hourly readings taken *pari passu* on a graduated staff, which had been set up in the sea in deep water, in order to afford a means of verifying the indications of the self-registering gauge. The station of Nawanár has thus been proved to be unsuitable for continuous tidal observations, extending over a long period, for it is only during the months of fine weather between November and May, that observations can be carried on there, otherwise than by setting up the tide-gauge on a staging erected for it out in deep water, the cost of which would be inadmissible.

Preliminary Results.—The preliminary results of the observations up to September 1874, as worked out by Captain Baird, show that the greatest range of the tide was—

14·8 feet at Okha.
19·6 „ Nawanár.
21·2 „ Hansthal.

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or two to four feet more in each instance than the ranges given in the marine Charts.

Very fairly approximate values of the progress of the tidal wave, up and down the Gulf, have also been obtained, showing that—

High-water occurs at Nawanár 1*h*. 5*m*. after Okha.
„ Hansthal 1 40 „
Low-water occurs at Nawanár 1 36 „
„ Hansthal 2 53 „

The results obtained from the combined tidal and levelling operations show that the mean sea-level is higher by 7 inches, at the head of the Gulf, and by 4 inches, midway up, than it is at the mouth of the Gulf.

The curves of the self-registering aneroid barometers were compared four times daily with a mercurial barometer, and the differences met with—after allowing for index errors—were usually so trivial and unimportant that every confidence may be felt in the general accuracy of the curves. The aneroids are of a delicate construction and are liable to get out of order, but as spare ones were available, no break of importance occurred at either station.

The anemometers were less satisfactory in their working, probably because they were so much more exposed to the vicissitudes of the weather. The long continuance of winds coming from the same quarter caused the direction gear to clog, and until this was discovered the recorded directions are to some extent incorrect. On the other hand, the velocity gear was kept in constant action by the strong winds prevailing. Several severe gales were recorded. The greatest velocities registered in 24 hours were—

620 miles at Okha on the 20th June 1874.
890 „ Nawanár „ 26th „
1130 „ Hansthal „ 5th Aug. „

On the latter date the anemometer of Hansthal recorded 270 miles in the three hours between 9 A.M. and noon. Captain Baird is not entirely satisfied with the performances of these instruments, but considering their small size (for the sake of lightness and portability), and their exposure to fierce winds, to rain and, worse than all, to the constant oxidising influence of the sea, Colonel Walker thinks it improbable that any instruments would, under similar circumstances, have given much better results.

The total rainfall during the monsoon of 1874, as registered by the rain-gauges set up at each station, was—

10·75 inches at Okha.
13·61 „ Nawanár.
18·40 „ Hansthal.
21·91 „ Rájkot (40 miles inland).

It will be seen that a greater range of tide, a greater velocity of wind and a greater rainfall have been registered at the head than at the mouth of the Gulf, and intermediate values at the midway station of Nawanár.

The scientific value of the observations is greatly increased by the contemporaneous observations of the barometric pressure, the velocity and direction of the wind, and the amount of rainfall; and it is believed that no series of tidal observations has been better furnished than these with the requisite data for separating local atmospheric influences from the true tidal constituents, which are caused by the varying position of the sun and moon.

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Spirit-levelling Operations.—At short distances round each station three blocks of stone were sunk in the ground to serve as bench-marks for future reference, and each of them was carefully connected with the zero of the tide-gauge. Bench-marks were also placed in position, one at about every 10 miles, from Okha station along the road to Hansthal and thence to Nawanár in Cutch across the Ran. Bench-marks were also laid down with reference to the nearest Great Trigonometrical Stations. During the field-season of 1874-75, Capt. Baird conducted a series of spirit-levelling operations for determining the present relative levels of the datum points of the three tidal stations, and of the stone bench-marks which had been laid down a year previously along the lines to be levelled over. The length of the main lines connecting the three tidal stations was 275 miles, which was levelled over independently by Capt. Baird and Narsing Dáss, in accordance with the rigorous system which has obtained for several years past in the G. T. Survey. 29 miles of branch lines were also executed, in order to connect the stations of the Káthiáwár triangulation with the tidal stations.

In working between Nawanár and Hansthal, Capt. Baird had to make a considerable *detour* round the head of the Gulf, crossing the Ran between Shikárpur and Mália. Several bench-marks were fixed on the Ran, and they will be important points of reference when these operations are repeated with the tidal observations some years hence, when a sufficient interval shall have elapsed to allow of the rising or sinking of the surface of the ground to an appreciable extent. The existing surface-level of the Ran has been obtained at a number of points, for Captain Baird took the precaution of having all the pins on which the levelling staves were set up, driven downwards until their heads were exactly flush with the surface of the ground.

Operations during the Monsoon.—Considerable anxiety was felt as to he possibility of securing continuous records during the monsoon, when eavy gales are prevalent; but every precaution was taken to strengthen he wooden observatories in which the instruments were set up, and to nticipate and provide for all possible contingencies; and it was most tisfactory that, although the monsoon of 1874 set in very severely and sted long, the observatories all stood firm, and the tide-gauges and other lf-registering instruments remained in good working order throughout e season.

Close of the Operations.—The carrying out of the periodical inspections during the monsoon was the most trying and difficult part of the operation. During the monsoon of 1874 this duty was performed entirely by Capt. Baird, who had generously given his assistant leave of absence on urgent private affairs at that time. It had, however, proved to be so arduous and to entail so much exertion and exposure, that Colonel Walker felt he would not be justified in requesting Capt. Baird to carry on the inspections during the monsoon of 1875. He was therefore directed to continue the registrations up to within a few days of the commencement of the monsoon, and then to dismantle all the stations, and remove the instruments.

Accordingly at the close of the field-season of 1874-75, the instruments were taken down and the observatories dismantled. At each station the vertical iron cylinder, in which the float of the gauge had acted, was left *in statu quo*, together with a length of the iron piping, extending about 50 feet seawards from the cylinder. The cylinder was filled with clean dry sand, and closed above with a thick planking, after which a massive pile of stones was raised over the ground around it, to

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serve the double object of a protection and an indication of the position for future reference.

The three bench-marks in the immediate vicinity of the cylinder, with each end of which the datum of the gauge had been connected, were similarly covered over. Finally the several cairns were placed under the protection of the local officials ; and it is to be hoped that the cylinders and bench-marks will be readily discovered whenever the second series of operations are commenced, and that they will be found to have remained undisturbed meanwhile.

Thus the periods during which the tidal heights have been continuously registered at the three stations are, $16\frac{1}{2}$ months at Okha, 14 months at Hansthal, 2 months at Nawanár in 1874, and 2 months more in 1875. As already noticed, simultaneous observations of the direction and velocity of the wind and of the barometric pressure were made by the anemograph and barograph which were set up at each station.

The long break in the registrations at Nawanár is to be regretted. But as the station lies nearly midway up the Gulf, it is probable that the values of the difference between the mean level for the periods of actual observation and the mean level for the entire year, which are given by the registrations at Okha and Hansthal, may be applied proportionately to the results at Nawanár, to obtain the mean level for the year there, and Capt. Baird found that this plan gave very accordant and promising results.

When all the observations were completed, the ordinates of the several curves were measured, (taking full account of clock-error whenever there was any) and then tabulated for each hour of the day. The numerical results thus obtained serve as the data on which the analysis of the observations was subsequently based.

Thus ended the first series of operations, to determine whether tl relations of land and sea are constant or changing. Col. Walker writes " Great credit is due to Capt. Baird for the manner in which he coı " ducted the task entrusted to him. The difficulties he had to conter " with in obtaining exact registrations continuously for such long perio " were very serious and formidable ; all the stations were situated at poiı " on the coast line which were very far from the nearest habited localiti " and the inspections during the season of monsoons, which work v " done entirely by himself, necessitated constant travelling during t " most inclement time of the year, and entailed an amount of risk a " exposure which would tell on a constitution of iron."

Final Results.—The analysis of the results of the observations has necessarily been a work of time and has only lately been completed. Col. Walker felt assured that it would be best performed with the assistance of Mr. Roberts of the Nautical Almanac Office in London, by whom all the tidal observations taken for the British Association had been, and are still being reduced and analysed, under the superintendence of Sir W. Thomson, and who had, previous to the commencement of the observations, aided Capt. Baird in the preparation of an account of the practical application of the harmonic analysis by which tidal observations are reduced for the British Association. Sanction was therefore obtained for Capt. Baird to remain in England and reduce his observations with Mr. Roberts' assistance. The results will be presently stated. But first it is necessary to give a brief epitome of the method of investigation which has been followed.

The rise and fall of the level of the ocean, twice, or nearly so, in twenty-four hours, is well known to be due to the attractions of the sun and the moon. If the orbit of the earth and that of the moon were quite circular and lay in the plane of the equator, and if the moon performed its revolution round the earth in the same time that the sun appears to revolve around the earth, then there would be two tides daily, differing from each other in form—should the sun and moon not be in conjunction—but recurring alike from day to day. The moon, however, makes her circuit of the earth in 48 minutes over the twenty-four hours, and thus the sun makes thirty apparent circuits of the earth while the moon is only making twenty-nine; moreover, the orbits of the earth and of the moon are not circular, nor are they situated in the plane of the equator. Thus the positions of the sun and moon, relatively to the earth, are momentarily varying in distance, declination and right ascension. Consequently, the level of the ocean is subject to momentary variations in the dynamical action of the disturbing bodies; and these cause a variety of tides which recur periodically, some in short, others in long periods.

In the present investigations, the short and the long period tides have been analysed by different methods. The former—which here embrace all tides recurring in periods of or about a day in duration, and in any aliquot part of the *quasi*-diurnal period—have been treated in accordance with the synthesis of Laplace. Thus a number of fictitious stars are assumed to move, each uniformly in the plane of the earth's equator, with angular velocities which are small in comparison with that of the earth's rotation, so that the period of each star is something not very different from 24 mean solar hours, and ranges between a minimum of 23 hours and a maximum of 27. Each star is supposed to produce a primary tide in its *quasi*-diurnal period, and also various sub-tides which run through their periods in $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ or some other aliquot part of the primary period; but of these sub-tides it may here be observed that some are considerably larger than their so-called primaries, as for instance, the lunar semidiurnal tide, the magnitude of which is enormously greater than that of the lunar diurnal. The primary is simply the tide of which the period is nearest to 24 mean solar hours.

Thus the momentarily varying level of the surface of the ocean is supposed to be the resultant of a large number of tides, each of which is perfectly independent of all the others, and has its own amplitude and period of revolution, which remain ever constant throughout all time. Occasionally several of the most important tides are in conjunction, and then the range between high and lower-water is a maximum, as at spring tides; at other times some tides are in opposition to others, and then the tidal range is a minimum, as occurs at neap tides.

Every tide may be represented by a circle of known diameter; and if we suppose a point to move uniformly right round the circumference of this circle so as to make a complete revolution in the time which is the tide's period, then the height of the point above or below the horizontal diameter of the circle at any moment, represents the height of the tide at that moment.

By the synthesis of Laplace we are able to find, from continuous observations of the varying level of the sea, the amplitude and the epoch (as they are called) of each of the several tides of which the height of the sea-level at any moment is the resultant. The amplitude is the radius of the representative circle, the epoch enables us to ascertain the point which the tide has reached at any given moment during its movement over the circumference of the circle. Thus when we know the amplitudes, the epochs and the velocities of rotation of any number of constituent tides, we are in a position to be able to compute and predict the height of the sea-level, at any future moment, at the station where the observations on which our calculations are based were taken.

The velocity of rotation of a tide rests primarily on certain combinations of the angular velocities of the earth's rotation round its axis, the moon's rotation round the earth, the earth's round the sun, and the progression of the moon's perigee, which are decided on *à priori* from theoretical considerations. These preliminary angular velocities are the arguments of the several fictitious stars of Laplace's method.

The portion of the height of the sea-level above or below its mean height (with reference to some fixed datum line), which is due to the combined influences of the several tides produced by any one of the fictitious stars, is given by the following well-known expression of the law of periodicity :

$$h = R_1 \cos(nt-\epsilon_1) + R_2 \cos(2nt-\epsilon_2) + R_3 \cos(3nt-\epsilon_3) + \dots$$

in which h is the height above mean sea at any moment, t is the time expressed in mean solar hours, commencing at 0^h astronomical reckoning, and n is the angular velocity of the star in degrees of arc per mean solar hour, so that $360° \div n$ denotes the period of the star in hours of mean time. R_1 is the amplitude, and ϵ_1 the epoch of the full-period tide ; R and ϵ_2, R_3 and ϵ_3, &c., are the amplitudes and epochs of the sub-tides, whose periods are one-half, one-third, &c., that of the primary period. The amplitude is the semi-diameter of the circle whose circumference indicates the path of a tide. The epoch is the arc which, when divided by the angular velocity of the tide, gives the hour-angle when the height of the tide is a maximum ; this occurs, on the day of starting, when $nt = \epsilon_1$ for a primary tide, when $2nt = \epsilon_2$ (and again 12 *quasi*-hours afterwards) for a tide whose period is half that of the primary, and so on.

Thus, if we now put h for the height of the sea-level at any moment and A for the value of the height of the mean sea-level which results from the combined influence of the whole of the fictitious stars, we have—

$$h = A + \Sigma \left\{ R_1 \cos(nt-\epsilon_1) + R_2 \cos(2nt-\epsilon_2) + \quad \dots \quad \right\}$$

where the symbol Σ stands for the summation of the whole of the term within the brackets, which relate to all the fictitious stars.

There are two principal stars, respectively called S and M for brevity, the first of which represents the mean sun, or that point in the plane of the earth's equator whose hour-angle is equal to mean solar time ; the second represents the mean moon, a point moving in the plane of the equator with an angular velocity equal to the mean angular velocity of the moon. The other fictitious stars respectively furnish the corrections to S and M for declination and parallax, to M for lunar evection and variation, and to S and M for the compound actions which produce what are called Helmboltz Tides, &c. The 24th part of the period of star S being an hour, that of any other of the fictitious stars may be conveniently spoken of, and is here called a *quasi*-hour.

To find the argument (the angular velocity n of the preceding formulæ) for each fictitious star, various combinations have to be made of the following fundamental angular velocities, *viz.* :

γ, the earth's rotation .... = 15.°0410686 per means solar hour.
σ, the moon's revolution round the earth. = 0·5490165 " "
η, the earth's revolution round the sun... = 0·0410686 " "
ϖ, the progression of the moon's perigee. = 0·0046418 " "

The several fictitious stars whose tides have been analysed in these investigations, are—

S, with argument $n = \gamma - \eta \quad = 15^{\circ}$
M " $\gamma - \sigma \quad = 14{\cdot}4920521$
K " $\gamma \quad = 15{\cdot}0410686$
O " $\gamma - 2\sigma \quad = 13{\cdot}9430356$
P " $\gamma - 2\eta \quad = 14{\cdot}9589314$
J " $\gamma + \sigma - \hat{\omega} \quad = 15{\cdot}5854433$
Q " $\gamma - 3\sigma + \hat{\omega} \quad = 13{\cdot}3986609$
μ " $\gamma - 2\sigma + \eta \quad = 13{\cdot}9841042$
N " $\gamma - \frac{3}{2}\sigma + \frac{1}{2}\hat{\omega} \quad = 14{\cdot}2198648$
L " $\gamma - \frac{1}{2}\sigma - \frac{1}{2}\hat{\omega} \quad = 14{\cdot}7642394$
ν " $\gamma - \frac{3}{2}\sigma - \frac{1}{2}\hat{\omega} + \eta \quad = 14{\cdot}2562915$
λ " $\gamma - \frac{1}{2}\sigma + \frac{1}{2}\hat{\omega} - \eta \quad = 14{\cdot}7278127$
M S " $\gamma - \frac{1}{2}\sigma - \frac{1}{2}\eta \quad = 14{\cdot}7460261$
and 2 SM " $\gamma + \sigma - 2\eta \quad = 15{\cdot}5079479$

The *quasi* hour angles of the several fictitious stars, other than S, at mean noon of the day of starting, were found by putting

$\gamma =$ the Sidereal time,
$\eta =$ the Sun's mean longitude $= \gamma$,
$\sigma =$ the Moon's mean longitude,
$\sigma - \hat{\omega}$ the Moon's mean anomaly,

and taking the correspounding numerical values of each element, for the hour and station, from the Nautical Almanac and Hansen's Lunar Tables, and then substituting these values in the preceding symbolic expressions for the hourly variations of the several stars.

The number of stars and the angular velocity of each star having thus been decided on, *à priori*, from theoretical considerations, the values of the constants R and ϵ for the tidal constituents of each star have to be determined from the evidence afforded by the tabulated values of the height of the sea-level for every hour of the day during the entire period of observation; this should not be less than 371 days. The values of the constants have been computed for the several tides at the three stations of Okha, Nawanár, and Hansthal, and are given below. It will be remembered that Okha is situated at the entrance to the Gulf of Cutch, Nawanár midway up the Gulf, and Hansthal at its upper extremity; also that continuous observations over a period of not less than 14 months were obtained at the upper and lower stations, whereas at the middle station, Nawanár, there was a break of several months, in consequence of an alteration of the foreshore during the monsoon of 1874; thus the results for Nawanár are far from being as exact and complete as those for the wo other stations.

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Table of the Constants.

	OKHA.	NAWANÁR.	HANSTHAL.
	Feet. °	Feet. °	Feet. °
The star S	R_1=0·0741, ϵ_1=149·89	Wanting.	R_1=0·1292, ϵ_1=164·01
	R_2=1·2224, ϵ_2= 14·37	R_2=1·8933, ϵ_2= 55·33	R_2=1·9277, ϵ_2= 84·51
	R_4=0·0132, ϵ_4=116·57	R_4=0·0131, ϵ_4=359·56	R_4=0·0211, ϵ_4= 61·74
	R_6=0·0030, ϵ_6= 20·92	Wanting.	R_6=0·0069, ϵ_6=166·57
	R_8=0·0006, ϵ_8=219·81	Ditto.	R_8=0·0025, ϵ_8=158·63
The star M	R_1=0·1122, ϵ_1=120·86	Ditto.	R_1=0·1208, ϵ_1=155·61
	R_2=3·6936, ϵ_2=348·08	R_2=5·8448, ϵ_2= 25·32	R_2=6·6291, ϵ_2= 46·52
	R_3=0·0289, ϵ_3= 22·10	Wanting.	R_3=0·0534, ϵ_3= 93·55
	R_4=0·1265, ϵ_4=108·88	R_4=0·1023, ϵ_4=275·00	R_4=0·6803, ϵ_4=331·55
	R_6=0·0056, ϵ_6=272·57	Wanting.	R_6=0·2760, ϵ_6=248·94
	R_8=0·0102, ϵ_8=100·06	Ditto.	R_8=0·0726, ϵ_8=154·36
The star K	R_1=1·5605, ϵ_1=146·60	R_1=1·6857, ϵ_1=156·00	R_1=1·6502, ϵ_1=174·60
	R_2=0·4207, ϵ_2= 24·82	R_2=0·4780, ϵ_2= 76·11	R_2=0·6767, ϵ_2= 88·63
The star O	R_1=0·8095, ϵ_1=322·67	R_1=0·7987, ϵ_1=332·04	R_1=0·8807, ϵ_1=340·76
The star P	R_1=0·3844, ϵ_1=319·94	R_1=0·2806, ϵ_1=342·02	R_1=0·3839, ϵ_1=353·65
The star J	R_1=0·1231, ϵ_1=176·32	R_1=0·1698, ϵ_1=191·77	R_1=0·1091, ϵ_1=222·61
The star Q	R_1=0·1596, ϵ_1=324·68	R_1=0·1697, ϵ_1=335·14	R_1=0·1618, ϵ_1=343·23
The star L	R_2=0·1511, ϵ_2=224·77	R_2=0·3569, ϵ_2=226·93	R_2=0·3892, ϵ_2=238·32
The star N	R_2=0·7551, ϵ_2=322·94	R_2=1·2205, ϵ_2= 11·72	R_2=1·1535, ϵ_2= 26·76
The star λ	R_2=0.0712, ϵ_2=204·40	R_2=0·1466, ϵ_2=251·10	R_2=0·2268, ϵ_2=219·57
The star ν	R_2=0·1592, ϵ_2= 8·50	R_2=0·2975, ϵ_2= 5·43	R_2=0·2864, ϵ_2= 48·24
The star μ	R_2=0·1896, ϵ_2=184·26	R_2=0·4026, ϵ_2=186·44	R_2=0·5569, ϵ_2=179·74
The star 2 SM	R_2=0·0435, ϵ_2=291·24	Wanting.	R_2=0·1309, ϵ_2=297·74
The star MS	R_4=0·0619, ϵ_4=112·37	Ditto.	R_4=0·3388, ϵ_4= 13·01

It will be seen that the principal tides are first the *quasi*-semi-diurnal of M, and then the semi-diurnal of S and the *quasi*-diurnal of K, which range from one-third to one-fourth of the former. S and M being the principal stars, their sub-tides, down to the three-hourly tide of S and the corresponding tide of M, have been computed. For K the *quasi*-diurnal and semi-diurnal tides were computed; for the stars O to Q only the primary tides. For the stars L to 2 SM there are no primaries, and the tides of longest period are the *quasi*-semi-diurnal; for MS the longest tide is the *quasi*-demi-semi-diurnal; these, being the principal ones for each star, have been computed.

Here it is necessary to observe that the number of sub-tides which have to be investigated in each instance, in order to evaluate the full influence of the star, is a matter which can only be decided after considerable experience of such investigations has been gained by the analysis of the tides at a great variety of stations. It was therefore left to Mr. Roberts, whose practical familiarity with the subject probably exceeds that of any other individual, to prescribe the number of terms to be computed for each star.

On inserting the numerical values of the constants R and ϵ in the general expression, and substituting for nt its values in succession for every hour from the starting-point, the height (in feet) of each tide and sub-tide may be computed for every hour. The sum of these gives the portion of the height of the sea-level at that hour which is due to the influence of the short-period tides. This usually far exceeds the portion which is due to all other causes, and is thus frequently taken to represent the whole height.

Should it be desired to compute the hourly heights for any day of any year, without commencing at the starting-point of the observations, as may be necessary when tidal predictions are required, the values of γ, η, σ, and $\hat{\omega}$ must be found, as stated on page 46, for mean noon of the day which may be adopted as the new starting-point; the *quasi*-hour-angles of the several fictitious stars, other than S, at that moment must then be found, after which those for the succeeding hours may be obtained by successive additions of the respective hourly increments which are due to each star.

The values of the constants R and ϵ having been determined for each of the three tidal stations, the next step taken was the calculation of the height of the sea-level at each hour, throughout the entire period of registration at each station. The differences between the observed and the computed values were then taken as the data for calculating the influence of variations in barometric pressure, and in the velocity and direction of the wind, on the sea-level. Equations were formed in which the unknown quantities were B, the effect of a barometric pressure of one inch, and N and E, the effects of the North and the East components respectively of winds blowing at the rate of 10 miles an hour. Of these equations there were as many as the number of days of observation; they were solved by the method of minimum squares. Corrections were then computed for the daily variations of the atmospheric influences on the sea-level, and were applied to the values of height resulting from the previous investigations of the short-period tides. Finally, the differences between the heights thus determined and those actually observed were taken as the data for calculating the influence of each of the long-period tides.

The evaluation of the atmospheric influences gave the following factors

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for changes of sea-level due to a barometric pressure of one inch, and to north and east winds travelling with a velocity of 10 miles per hour :

	At Okha.	At Hansthal.
Barometric pressure	+ 0·356 feet	— 0·438 feet
North Wind	— 0·191 „	— 0·262 „
East Wind	+ 0·161 „	+ 0·087 „

These results are not satisfactory; the height of the sea-level at Okha appears to increase with an increase of barometric pressure, which is scarcely possible. It happens that at this station the changes of pressure occurred, as a rule, simultaneously with the changes of wind; and thus it is impossible to determine the separate effect of each, otherwise than by some arbitrary method of treatment. The observations will therefore be again analysed, with a view to ascertaining whether they may not be made to yield more consistent results. Meanwhile, the values of the atmospheric factors already obtained must be considered to be only approximate, giving fairly accurate results when employed collectively but not individually.

Of the constants for the long-period tides the following values have been computed for the stations of Okha and Hansthal, after the elimination of atmospheric influences, by employing the preliminary values of the factors which are given in the preceding paragraph. At Nawanár sufficient observations are not forthcoming for the evaluation of either the atmospheric or the long-period tides.

Long-period tides, and their Constants.

$(\sigma-\hat{\omega})$	Lunar monthly elliptic tide,
$2\,\sigma$	Lunar fortnightly declinational tide,
$2\,(\sigma-\eta)$	Luni-solar synodic fortnightly tide,
η	Solar annual elliptic tide,
$2\,\eta$	Solar semi-annual declinational tide,

OKHA. Feet.	°	Tide.	HANSTHAL. Feet.	°
R = 0·058, ϵ =	311·38	$(\sigma-\hat{\omega})$	R=0·107, ϵ =	14·17
„ 0·070, „	52·73	$2\,\sigma$	„ 0·142, „	45·74
„ 0·136, „	249·19	$2\,(\sigma-\eta)$	„ 0·163, „	11·76
„ 0·162, „	3·11	η	„ 0·024, „	195·32
„ 0·121, „	144·75	$2\,\eta$	„ 0·090, „	156·38

(61/E)